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On the Age and Race of the Japanese Sardine, *Sardinia melanosticta* (Temminck and Schlegel)

By

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(With 10 Text-figures and 15 Tables)

The Japanese sardine, *Sardinia melanosticta* (T. and S.) is one of the most important fishes in Japan, economically, its annual yield usually amounting to more than a half of the total yield of all the fishes caught around Japan. As the data for a scientific study of the sardine fishery in Japan, with statistics as basis, the writer has attempted to determine the age of the sardine by reading its scales and to ascertain its race from variations in the number of vertebral bones, the age composition of catch, and other points. The writer takes this opportunity of expressing his sincere thanks to Profs. I. Amemiya and M. Tauti for their numerous suggestions in preparing this paper.

1. The age of the sardine

The age of fish can be determined from the number of rings that form on the scale, on the otolith, and on the centrum of the vertebral bone, and also by tracing the seasonal changes in weight and body length in the course of a year. The otolith and vertebral bone of the sardine are, however, not only too small to admit exact measurement, but also unsuitable for this purpose, because the sample is usually preserved in formalin. In the circumstances, the writer determines the age of the sardine from the rings formed on the scale, although unfortunately the scale cannot always be collected from a definite portion of the body as easily as the otolith and vertebral bone. The scale of the sardine easily fall off in fishing and also during transit to the laboratory. The scales collected were mostly from the side slightly behind the operculum. These are placed in 4% solution of potassium hydroxide for 1 or 2 days to clean, after which they are well washed with running water for a day or more until the water ceases to give a

reddish colouration by the addition of a drop of 0.5% solution of phenolphthalen. From 10 to 20 of these scales are then placed between two slides and measured under the microscope after being thoroughly dried.

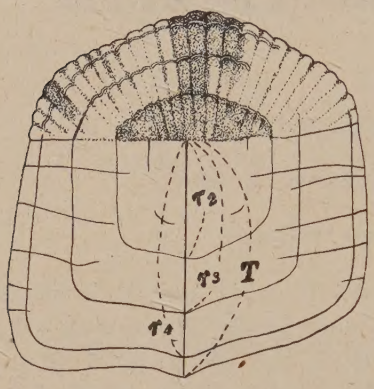

Fig. 1. Diagram of sardine scale.

The length of the covered portion (T mm) and the radii of the rings (r mm) are measured (Fig. 1; Tables 1–4). The scales collected from nearly the same part of the fish vary not only in length (T mm), but also in radii (r mm) and even in the number of rings (Figs. 2, 3). The $(2n+1)$st. ring is usually indistinct. After the 2nd ring has formed, the 1st ring (r_1), especially, becomes incomplete, inconspicuous, and scarcely recognizable. Since the 1st ring is fairly distinct only on scales of individuals less than 11.5 cm in body length, 1 or 5 complete rings are usually found on the scales of sardines that exceed 11.5 cm in length (Fig. 3). Out of 460 mature individuals, Mr. J. NAKAI observed 3 that had 7 rings (6 in his data) on the scale and only 1 that had 8 rings (7 in his data). At any rate, those with more than 7 rings are very scarce in the Japanese sardine group.

The length of the covered portion (T mm) correlates well with the body length (l cm) (Fig. 4). The relation may be expressed by the formula

$$\frac{l_1}{l} = \frac{T_1 + 1.0}{T + 1.0} \quad \cdots\cdots\cdots\cdots\cdots\cdots (1)$$

The length of the covered portion (T mm) increases with the growth of the body length (l cm) in such a definite ratio as above. As their standard deviation (S.D. in tables) are usually less than 1/10 of the average, the average radii of the rings may be considered reliable. The difference in the average radii of any two neighbouring rings being very small, their reliability (R) is tested by the formula

$$R = \frac{r_{n+1} - r_n}{\sqrt{\frac{d^2_{n+1} + d^2_n}{2}}} \quad \cdots\cdots\cdots\cdots\cdots\cdots (2)$$

Table 1. Body length (l cm), length of covered portion of scale (T mm), and radius of ring (r mm).

	No.	l	T	s.d.	r_1	s.d.	r_2	s.d.
Kinuura Wan (24) Sept. 2	1	9.8	2.50	.00				
	2	10.1	2.38	.13				
	3	10.2	2.78	.11				
	4	10.3	2.80	.17				
	5	10.4	2.69	.24				
	6	10.5	2.76	.29				
	7	10.8	2.77	.24				
	8	10.9	2.79	.17				
	9	11.1	2.87	.23				
	10	11.4	2.89	.21				
	11	11.5	2.81	.27				
	12	11.5	3.18	.30				
	13	11.8	2.97	.30				
St. 43 (1) Aug. 22	1	11.4	3.64	.31	2.92	.23		
	2	11.5	4.10	.49	3.36	.32		
	3	11.5	3.91	.23	3.00	.23		
	4	11.6	3.87	.30	3.03	.36		
	5	11.8	3.83	.13	2.89	.07		
	6	12.0	3.81	.26	2.87	.19		
	7	12.1	3.81	.26	3.12	.26		
	8	12.3	3.20	.34	3.01	.21		
		Mean			3.02	.47		
Sin-Maiko (24) Oct. 13	1	9.5	2.58	.22				
	2	10.1	3.90	.21	3.46	.10		
	3	10.7	4.32	.10	3.35	.19		
	4	10.7	3.58	.13	3.06	.18		
	5	10.9	4.22	.15	3.22	.39		
	6	11.5	3.35	.25	2.91	.14		
	7	11.7	3.54	.08	3.00	.21		
		Mean			3.17	.28		
Mori (7) Dec. 2	1	12.3	3.43	.09			3.00	.00
	2	12.4	3.56	.21				
	3	12.5	3.32	.17				
	4	13.1	3.93	.19				
	5	13.4	3.56	.45				
	6	13.9	3.61	.43			3.28	.22
	7	14.0	4.09	.11			3.70	.20
	8	14.1	3.96	.16			3.20	.00
	9	16.4	4.78	.21	2.78	.42	3.73	.29
		Mean			2.78	.42	3.38	.29

	No.	l	T	s.d.	r_1	s.d.	r_2	s.d.
Miya (23) Nov. 12	1	12.3	3.19	.39				
	2	12.5	3.83	.13	3.08	.12		
	3	12.8	3.63	.13	2.72	.32		
	4	13.0	3.63	.35	2.68	.13	3.43	.33
	5	13.0	3.85	.14	2.80	.21	3.52	.07
	6	13.1	3.66	.23	2.52	.26	3.23	.18
	7	13.2	3.66	.19	2.73	.33	3.32	.22
	8	13.2	3.64	.13	2.20	.00	2.70	.00
	9	13.3	4.10	.19	2.98	.15	3.66	.21
	10	13.3	3.59	.24	2.30	.20	3.45	.25
	11	13.4	3.86	.19	2.73	.24	3.38	.12
	12	13.5	3.97	.20	2.99	.15	3.61	.21
	13	13.6	4.10	.23	2.93	.30	3.63	.23
	14	13.6	3.88	.17	2.77	.23	3.55	.12
	15	13.8	3.96	.20	2.84	.16	3.73	.20
	16	14.0	4.22	.25	2.87	.34	3.73	.19
		Mean			2.74	.28	3.46	.26
Onahama (16) Jan. 27	1	12.9	2.72	.13	2.98	.21	—	—
	2	13.3	3.74	.16	—	—	3.36	.11
	3	14.8	4.04	.25	—	—	3.22	.26
	4	14.8	4.41	.28	2.51	.11	3.62	.20
	5	15.0	4.23	.18	2.79	.09	3.50	.12
	6	15.0	4.33	.26	3.07	.09	3.70	.24
		Mean			2.84		3.48	
Onyuku (19) May 2	1	11.9	3.65	.09				
	2	12.0	3.88	.28			3.36	.25
	3	12.4	3.60	.00			3.30	.00
	4	12.5	3.71	.20			3.35	.00
	5	12.8	3.80	.13			3.40	.15
	6	12.9	3.55	.05			3.23	.12
	7	13.7	3.97	.37			3.10	.33
	8	14.1	4.20	.00			3.40	.00
		Mean					3.30	.27
Toyoura (6) Dec. 9	1	14.1	3.71	.29	3.03	.24		
	2	15.3	3.96	.26	2.96	.17	3.40	.11
	3	15.5	4.49	.13	3.13	.14	3.82	.17
	4	16.2	4.49	.17	3.18	.16	3.86	.12
		Mean			3.07	.20	3.72	.23

Table 2. Body length (l cm), length of covered portion of scale (T mm), and radius of ring (r mm).

	No.	l	T	s.d.	r_1	s.d.	r_2	s.d.	r_3	s.d.	r_4			
Muroran (5) Oct. 20, '38	1	15.1	4.40	.26			2.73	.38	3.63	.27				
	2	15.4	3.83	.41			2.50	.48	3.08	.41				
	3	15.5	4.58	.10			3.30	.24	4.14	.40				
	4	15.7	4.92	.34			3.22	.30	4.09	.32	4.63	.13		
	5	15.8	4.02	.13			2.53	.38	3.52	.44				
	6	15.9	4.41	.20			2.84	.30	3.59	.28				
	7	16.0	4.78	.19			2.83	.16	3.74	.14	4.52	.16		
	8	16.0	4.58	.30			3.38	.19	3.87	.25				
	9	16.1	4.70	.35			3.17	.24	3.78	.23				
	10	16.2	4.94	.22			2.98	.13	3.68	.16	4.31	.24		
	11	16.6	4.50	.22			3.09	.19	3.74	.13	4.50	.00		
	12	16.6	4.46	.33			2.92	.41	3.93	.45				
	13	17.0	4.88	.25			3.18	.27	4.11	.23	4.50	.23		
	14	17.1	5.10	.34			3.28	.24	4.11	.29				
	15	17.4	5.17	.17			3.21	.44	3.73	.19				
	16	17.4	5.20	.00			3.10	.00	3.80	.00				
	17	17.5	4.25	.25			2.95	.15	3.65	.15	4.05	.15		
		Mean					3.08	.35	3.80	.40	4.43	.25		
Nakaminato (17) May 12	1	15.1	4.34	.29	—		3.38	.15	3.88	.25				
	2	15.5	4.47	.23	2.57	.18	3.41	.32	4.20	.29				
	3	15.5	4.39	.18	—	—	3.35	.15	4.20	.19				
	4	15.6	4.62	.31	—	—	—	—	3.87	.29				
	5	15.7	4.40	.29	—	—	3.42	.24	4.16	.22				
	6	15.8	4.65	.13	3.00	.00	3.24	.00	4.06	.21				
	7	15.8	4.69	.33	2.94	.29	—	—	3.95	.29				
	8	16.1	4.67	.17	2.60	.16	—	—	3.99	.15				
	9	16.2	4.20	.15	2.60	.08	3.63	.17	3.87	.20				
	10	16.7	4.56	.08	—	—	3.52	.04	4.32	.10				
		Mean			2.74	.31	3.42	.44	4.05	.30				
Sigazima (16) Jan. 30	1	16.5	4.38	.41	3.19	.32	3.97	.23						
	2	16.7	5.27	.36	3.65	.11	4.63	.29	4.93	.28				
	3	16.8	4.21	.43	2.76	.30	3.75	.22						
	4	16.9	4.73	.46	2.76	.41	3.56	.44	4.43	.59				
	5	17.2	4.93	.22	2.67	.17	3.96	.22	4.76	.39				
	6	17.4	4.53	.16	2.62	.19	3.44	.22	4.23	.17				
	7	17.5	4.66	.20	3.03	.32	3.82	.37	4.36	.31				
		Mean			2.91	.38	3.82	.45	4.54	.45				
Mori (7) Nov. 2	1	13.7	4.10	.31			2.57	.10	3.36	.25				
	2	14.7	4.51	.68			3.30	.30	4.00	.51				
	3	15.3	4.30	.24			2.97	.30	3.77	.27				
	4	15.3	4.41	.17			2.93	.18	3.66	.19				
	5	15.8	4.85	.26			3.35	.24	4.51	.30				
	6	16.1	4.11	.15			3.16	.13	3.69	.16				
	7	16.4	4.89	.23			3.50	.28	4.46	.21				
	8	17.1	4.86	.25			3.43	.12	4.40	.12				
	9	17.4	5.20	.44			3.40	.25	3.99	.30	4.56	.26	4.96	.22
		Mean					3.22	.34	3.99	.44	4.56	.26	4.96	.22

Table 3. Body length (l cm), length of covered portion of scale (T mm), and radius of ring (r mm).

	No.	l	T	s.d.	r_1	s.d.	r_2	s.d.	r_3	s.d.	r_4	s.d.	r_5	s.d.
Randomari (1) Aug. —	1	17.1	4.99	.18	2.68	.20	3.66	.22	4.56	.21				
	2	17.9	5.49	.23	3.01	.19	4.03	.14	4.91	.22	5.26	.20		
	3	18.1	5.34	.27	2.93	.43	3.60	.59	4.71	.22	5.10	.21		
	4	18.4	5.00	.50	2.95	.05	3.65	.15	4.25	.25	4.70	.30		
	5	19.1	5.79	.23	3.43	.39	4.19	.33	4.88	.26	5.47	.33		
		Mean			3.01	.42	3.86	.36	4.74	.29	5.25	.35		
Ryôto (6) May 8	1	17.2	5.26	.22	2.80	.13	3.40	.17	4.02	.06	4.82	.25		
	2	17.6	4.65	.05	3.00	.00	3.95	.05	4.20	.00	4.50	.00		
	3	17.8	4.96	.40	2.78	.19	3.83	.32	4.51	.40	4.93	.23		
	4	17.9	5.28	.23	2.85	.16	3.63	.12	4.20	.28	5.10	.32		
	5	17.9	5.30	.30	3.46	.21	3.99	.19	4.52	.17	5.09	.24		
	6	18.0	5.04	.22	3.28	.18	3.91	.17	4.51	.27	4.87	.22		
	7	18.4	4.63	.18	2.97	.11	3.50	.15	4.02	.12	4.50	.15		
	8	18.4	5.01	.36	2.90	.16	3.75	.24	4.31	.21	4.78	.20		
	9	17.3	4.91	.16	2.75	.10	3.44	.13	4.30	.00	4.65	.17		
		Mean			3.02	.29	3.76	.28	4.32	.31	4.86	.30		
Tutizaki (3) May 26	1	16.8	4.45	.19	2.74	.15	3.14	.12	3.97	.22	4.25	.24		
	2	16.9	4.58	.23	2.66	.18	3.50	.17	4.16	.24				
	3	17.1	4.98	.15	2.75	.19	3.40	.14	3.80	.16	4.35	.13	4.78	.15
	4	17.1	4.90	.18	2.58	.13	3.00	.13	3.77	.31	4.04	.24	4.60	.16
	5	18.1	5.31	.13	2.77	.15	3.40	.14	4.18	.18	4.70	.16		
	6	18.5	5.62	.40	—	—	3.42	.12	4.18	.31	4.78	.37	5.30	.41
		Mean			2.70	.18	3.30	.23	3.94	.32	4.39	.33	4.84	.41
Namerikawa (7) Feb. 21	1	15.7	4.81	.19	2.94	.13	3.67	.16	4.60	.17				
	2	16.2	4.89	.14	3.02	.13	3.94	.16	4.42	.18				
	3	16.3	5.08	.08	3.00	.06	3.78	.09	4.30	.07				
	4	16.3	4.63	.08	2.67	.21	3.85	.20	4.30	.07				
	5	16.5	5.34	.23	2.58	.10	3.76	.18	4.36	.13	4.84	.19		
	6	16.7	5.08	.12	3.19	.13	3.91	.12	4.59	.09				
	7	17.1	5.60	.10	3.10	.10	4.00	.00	4.60	.00	5.07	.09	5.47	.13
	8	17.4	5.87	.11	3.05	.33	3.92	.38	4.70	.19	5.02	.32	5.68	.10
	9	18.3	5.72	.28	3.13	.14	3.82	.22	4.57	.36	5.18	.25	5.60	.12
	10	19.5	5.66	.24	3.05	.36	3.90	.10	4.70	.22	5.10	.29	5.65	.15
		Mean			2.94	.27	3.86	.23	4.50	.23	5.08	.27	5.61	.25
Miyatu (11) Jan. 20	1	15.7	5.03	.29	3.17	.26	3.90	.30	4.47	.38				
	2	16.8	4.28	.36	3.00	.42	3.50	.33	—	—				
	3	16.9	5.06	.40	3.41	.00	4.24	.29	4.88	.44				
	4	17.0	5.47	.27	2.65	.02	3.32	.20	—					
	5	17.2	5.35	.28	3.06	.17	4.03	.11	5.00	.37				
	6	17.8	5.31	.61	2.65	.21	3.53	.30	4.07	.42	4.80	.64	5.20	.57
	7	17.9	4.76	.23	2.79	.14	3.76	.25	4.48	.29				
	8	18.2	4.63	.32	3.03	.11	3.55	.09	3.98	.11	4.67	.13	4.67	.24
	9	18.3	5.80	.00	3.00	.00	4.00	.00	4.50	.00	5.00	.00	5.50	.00
		Mean			2.85	.31	3.50	.39	4.17	.34	4.74	.50	5.04	.44

Table 4. Body length (l cm), length of covered portion of scale (T mm), and radius of ring (r mm).

	No.	l	T	s.d.	r_2	s.d.	r_3	s.d.	r_4	s.d.	r_5	s.d.	r_6	s.d.
Miyatu (11) Mar. 7	1	17.3	4.45	.34	2.78	.38	3.70	.31	4.23	.27				
	2	17.6	5.34	.19	3.71	.16	4.48	.20	5.01	.21				
	3	18.8	5.25	.27	3.05	.19	3.80	.13	4.33	.22	4.78	.32	5.08	.26
	4	19.5	5.27	.27	2.99	.28	3.80	.31	4.50	.40	4.99	.37	5.36	.28
	5	Mean			3.22	.40	4.20	.41	4.61	.43	4.70	.21	5.27	.30
Uratomi (14) Mar. 22	1	15.5	5.70	.37	3.03	.33	3.90	.38	4.46	.38				
	2	16.6	5.38	.36	3.05	.17	3.80	.30	4.45	.18	4.88	.22	5.15	.34
	3	17.6	5.13	.19	3.05	.26	3.65	.47	4.35	.09	4.58	.04	4.90	.16
		Mean			3.05	.25	3.77	.33	4.40	.29	4.70	.21	5.03	.28
Sigazima (16) Feb. 2 8	1	18.4	5.92	.36	2.65	.22	3.61	.24	4.48	.22	5.18	.41	5.75	.32
	2	18.7	5.47	.30	2.40	.40	3.27	.46	4.20	.37	4.77	.26	5.23	.29
	3	18.7	5.74	.37	2.41	.15	3.64	.27	4.51	.32	5.08	.35	5.50	.37
	4	18.8	5.31	.28	2.98	.30	3.58	.23	4.25	.21	4.83	.24	5.15	.27
		Mean			2.45	.32	3.58	.28	4.54	.31	5.02	.36	5.47	.41
Hukuyosi (17) Apr. 6	1	16.6	4.17	.31	2.83	.39	3.50	.37	4.66	.29				
	2	16.7	5.01	.24	3.10	.10	3.86	.13	4.38	.19	4.85	.21		
	3	17.6	4.90	.35	3.08	.19	3.56	.23	4.59	.29				
	4	19.0	5.76	.58	2.94	.22	3.80	.31	4.39	.43	4.92	.38	5.44	.26
	5	19.4	5.87	.20	3.07	.14	3.71	.15	4.51	.15	5.48	.17	5.79	.46
	6	19.6	5.95	.36	3.43	.45	4.26	.51	4.96	.41	5.40	.39	5.73	.43
		Mean			2.98	.40	3.92	.51	4.56	.59	5.08	.38	5.64	.43
Hukuyosi (17) Apr. 18	1	17.0	4.08	.25	2.48	.14	3.08	.24	3.35	.21				
	2	17.1	4.27	.32	2.32	.19	3.93	.27						
	3	17.2	4.30	.38	2.57	.18	3.50	.26						
	4	17.2	4.62	.30	3.13	.18	4.20	.21						
	5	17.5	4.68	.32	2.72	.41	3.96	.24	4.47	.18				
	6	17.5	5.01	.12	3.00	.14	3.59	.08	4.73	.14				
	7	17.7	5.03	.35	2.34	.36	2.87	.32	3.56	.36	4.38	.32	4.81	.35
	8	17.7	5.19	.21	3.49	.10	4.52	.25	5.03	.22				
	9	17.7	5.26	.24	2.67	.18	3.83	.17	4.74	.19	5.10	.30		
	10	17.7	5.27	.34	3.21	.17	4.16	.40	4.92	.42				
	11	17.7	5.30	.15	3.37	.33	4.29	.18	4.99	.11				
	12	17.8	5.35	.13	2.89	.23	3.99	.25	4.88	.32				
	13	17.8	5.39	.19	2.34	.16	3.04	.25	3.63	.18	4.62	.20	5.21	.23
	14	18.0	5.40	.46	2.87	.24	3.61	.39	4.16	.35	4.86	.38	5.19	.40
	15	18.0	5.50	.43	2.90	.14	3.90	.22	4.63	.26	5.00	.36	5.27	.38
	16	18.5	5.54	.13	2.39	.08	3.47	.08	—	—	—	—	5.28	.22
	17	18.9	5.54	.00	2.57	.09	3.56	.10	3.71	.58	4.82	.44	5.26	.30
	18	18.9	5.70	.14	3.13	.15	3.73	.26	4.20	.28	5.00	.14	5.50	.06
	19	19.1	5.83	.22	3.19	.19	—	—	4.69	.25		—	5.58	.22
	20	19.4	5.89	.48	3.04	.31	3.93	.44	4.61	.42	5.35	.38	5.83	.13
		Mean			2.84	.42	3.77	.51	4.52	.63	5.28	.64	5.46	.59

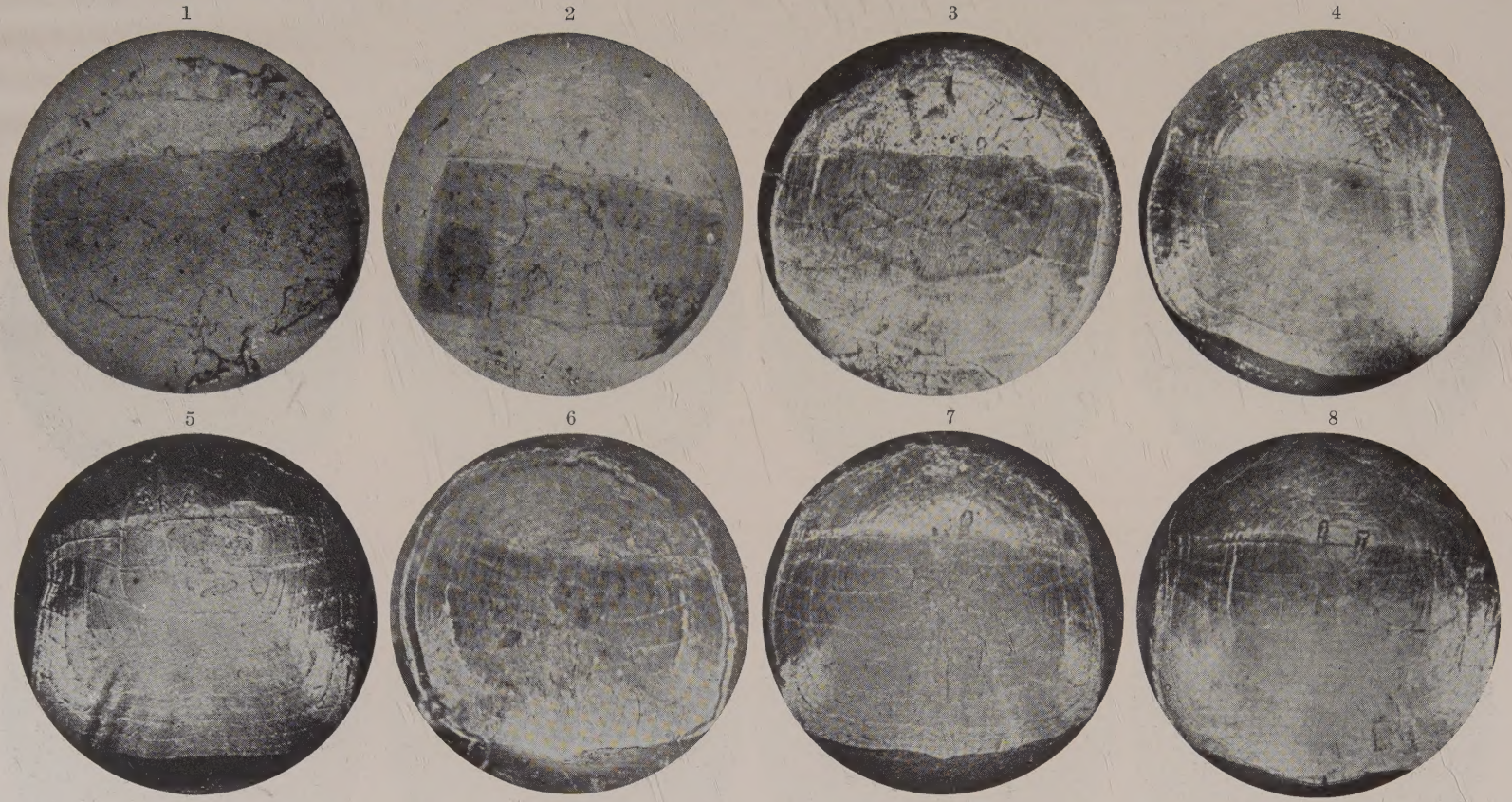

Fig. 2. Sardine scales with several rings. I.

1. Nagai, July 16; 9.5 cm, no ring: 2. scale from same individual, 1 ring: 3. Kinuura Wan (24), Sept. 2, 10.0 cm, 1 ring: 4. Turuga (10), May 30, 18.3 cm, 3 rings with inconspicuous 1st. ring: 5. Turuga (10), May 30, 16.8 cm, 5 rings: 6. Wakinozawa (9), August, 13.6 cm, 2 rings with inconspicuous 1st. ring: 7. Wakinozawa (9), Aug., 15.0 cm, 3 rings: 8. Senzaki (15), May 30, 18.3 cm, 5 rings with inconspicuous 1st.ring.

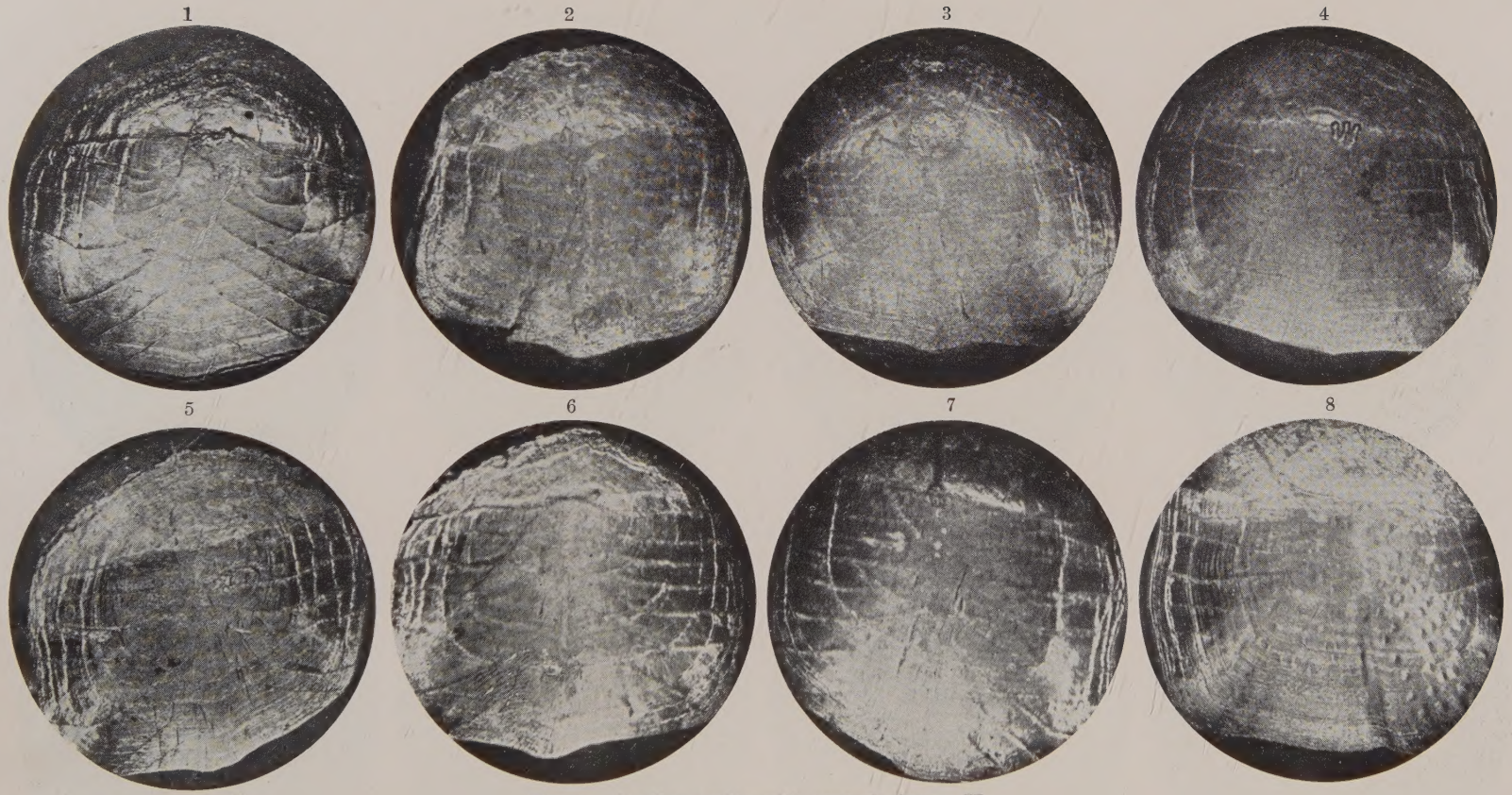

Fig. 3. Sardine scales with several rings. II.

1. Usetu (8), Feb., 15.7 cm, 4 rings: 2. Namerikawa (7), Jan. 20, 15.6 cm, 3 rings with inconspicuous 1st. ring: 3. Turuga (10), May 30, 17.3 cm, 3 rings with inconspicuous 1st. ring: 4. Usetu (8), June 2, 17.2cm, 3 rings with inconspicuous 1st. ring: 5. Senzaki (15), May 30, 17.1 cm, 4 rings with inconspicuous 1st. ring: 6. Senzaki (15), May 30, 19.2 cm, 6 rings: 7. Senzaki (15), May 30, 18.5 cm, 4 rings with inconspicuous 1st. and 3rd. rings: 8. Hukawura (2), July 4, 19.9 cm, 3 rings with inconspicuous 1st., 3rd., and 4th. rings.

Table 5. Average radius of ring on scale of each group.

Fishing Ground	Date	1st. ring		2nd. ring		3rd. ring		4th. ring		5th. ring		6th. ring	
		mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
St. 43 (1)	8.22	3.02	.47										
Muroran (5)	10.22	—	—	3.08	.35	3.80	.40	4.43	.25				
Toyoura (6)	12. 9	—	—	3.07	.20	3.72	.23						
Mori (7)	11. 2	—	—	3.22	.34	3.99	.44	4.56	.26	4.96	.22		
Mori (7)	12. 2	2.78	.42	3.38	.29								
Onahama (16)	1.27	2.97	.39	3.60	.20								
Nakaminato (17)	5.12	2.74		3.42		4.05							
Onzyûku (19)	5. 2	—	—	3.30									
Sin-Maiko (24)	10. 3	3.17	.28										
Miya (22)	11.12	2.74											
Mean (Pacific coast)		2.90	.16	3.30	.18	3.89	.13	4.50	.07	4.96	.22		
Randomari (1)	8.15	—	—	3.01	.42	3.86	.36	4.74	.29	5.25	.35		
Tutizaki (3)	5.26	2.70	.18	3.30	.23	3.94	.32	4.39	.33	4.84	.41		
Ryôtu (6)	5. 8	—	—	3.02	.29	3.76	.28	4.32	.31	4.86	.30		
Namerikawa (7)	5.29	—	—	2.94	.27	3.86	.23	4.50	.23	5.08	.27	5.60	.25
Usetu (8)	5.12	—	—	2.75	.10	3.44	.13	4.30	.00	4.65	.17		
Miyatu (11)	1.20	—	—	2.85	.31	3.50	.39	4.17	.34	4.74	.50	5.04	.44
Miyatu (11)	3.—	—	—	3.22	.40	4.20	.41	4.60	.43	4.92	.36	5.27	.36
Uratomi (14)	3.—	—	—	3.05	.25	3.77	.33	4.40	.29	4.70	.21	5.03	.28
Mean (coast of Japan Sea)		2.70	.18	3.08	.18	3.79	.23	4.43	.17	4.88	.19	5.24	.23
Sigazima (16)	1.30	—	—	2.91	.38	3.82	.45	4.54	.45				
Sigazima (16)	2.28	—	—	2.45	.32	3.58	.28	4.54	.31	5.02	.36	5.47	.41
Hukuyosi (17)	4. 6	—	—	2.98	.40	3.92	.51	4.56	.59	5.08	.38	5.64	.43
Hukuyosi (17)	4.18	—	—	2.84	.42	3.77	.51	4.52	.63	5.28	.64	5.46	.59
Mean (coast of Kyûsyû)				2.80	.21	3.77	.12	4.54	.01	5.13	.11	5.52	.08
Mean (around Japan)		**2.88**	**.17**	**3.10**	**.27**	**3.81**	**.19**	**4.47**	**.13**	**4.93**	**.20**	**5.36**	**.23**

where r_n and r_{n+1} are the average radii of the nth and $(n+1)$st rings, and d_n and d_{n+1} their standard deviations. R is greater than 3 in 112 cases out of 136 (82%) between the 2nd and 3rd rings, and also in 54 cases out of 83 (65%) between the 3rd and 4th rings. Only 36% of R exceed 3 in the differences between the 4th and 5th rings, and 30% in the differences between the 5th and 6th rings. The distances between the 2nd, 3rd, and 4th rings are about 0.7 mm, while those between the 4th, 5th, and 6th rings are only 0.45 mm, in addition to which the standard deviations of all radii increase gradually in the outer rings. Therefore, the reliability (R) must diminish in rings of both the 5th and 6th beyond that expected. The maximal radius of 2nd ring is 3.38 ± 0.29 mm, the minimal 2.45 ± 0.13 mm, and the mean 3.10 ± 0.27 mm. The average radii of each ring varies considerably, although in their construction show no differences (Table 5).

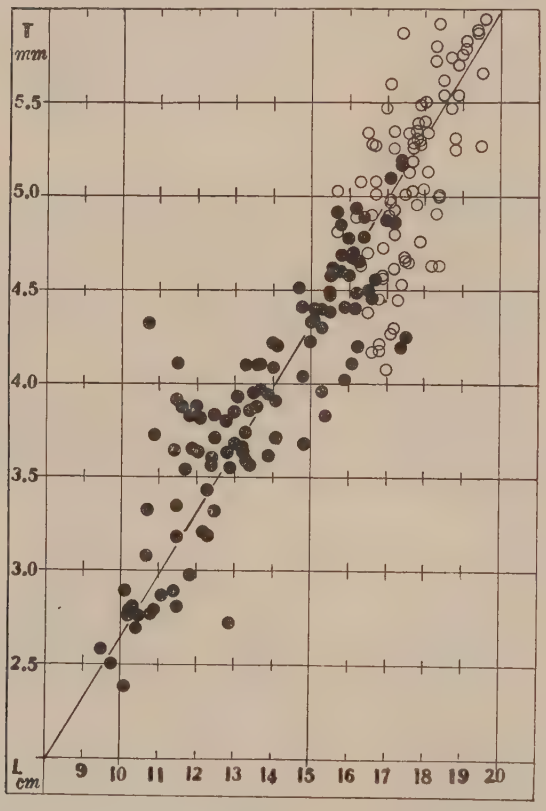

Fig. 4. Correlation between the body length (l cm) and the total length of covered portion of scale (T mm).

The nth ring completes, when the covered portion (T mm) attains a length equal to its radius (r_n mm). When the nth ring is formed, the body length (l_n cm) can be computed by the following formula, which is based on the relation expressed by formula 1 and shown in Fig. 4.

$$l_n=2.86\,r_n+2.84 \quad \ldots\ldots\ldots\ldots\ldots (3)$$

Thus, $l_1=11.0\pm0.4$ cm, $l_2=11.5\pm0.7$ cm, $l_3=13.5\pm0.5$ cm $l_4=15.5$

± 0.3 cm, $l_5 = 17.0 \pm 0.5$ cm, and $l_6 = 18.0 \pm 0.6$ cm. Therefore, the scale of an individual measuring less than 11.0 cm has no ring, that from 11.1 cm (l_1) to 11.5 cm (l_2) has only one ring, that from 11.6 cm to 13.5 cm (l_3) has two rings, and so on. The relation between body length (l cm) and the number of rings is somewhat variable owing to the fact that body length must vary with the condition of growth, whether too good or too bad, although the rings increase independently. Neverthless, more than 60% of the individuals having body lengths ranging from l_n to l_{n+1} are provided with n rings on the scale, as shown in Table 6. Consequently, the number of rings on the scale can be ascertained fairly accurately from the body length alone. The growth rate of the Japanese sardine shows no remarkable variation with

Table 6. Relations between the compositions assumed based on the number of rings and on the length.

	Length	Number of rings						
		1,0	2	3	4	5	6	Length group (Corel. Coef.)
Tables 2~4	<11.5 cm.	13	8					21
	11.6–13.5	8	15	10				33
	13.6–15.5		7	19	1			27
	15.6–17.0			21	17	4	2	44
	17.1–18.0			8	15	10	11	44
	<18.1 cm.					7	18	25
	Ring group	21	30	58	33	21	31	($r = +0.62$)
Turuga, Mar. 24	11.6–13.5		15		1			16
	13.6–15.5		15	4	3			22
	15.6–17.0			1	1			2
	Ring group		30	5	5			($r = +0.71$)
Turuga, Apr. 17	15.6–17.0				9			9
	17.1–18.0			2	27		9	38
	18.1 cm.				12		33	45
	Ring group			2	48	0	42	($r = +0.95$)
Turuga, May. 27	13.5–15.5				11			11
	15.6–17.0			2	25		3	30
	17.1–18.0			1	33		8	42
	18.1 cm.				3		8	11
	Ring group			3	72	0	19	($r = +0.69$)

locality, whereas that of the Spanish sardine, *S. pilchardus pilchardus* (Walb.) varies locally to a wide extent (J. Le Gall, 1937).

Herring and some salmonid fishes form a ring every year, namely, age rings. The writer examined also the ring formed on the centrum of the vertebral bone of the scomber, bonito, etc. (H. Aikawa, 1937, '38) and concluded that a ring is formed every year. Are the rings on sardine scale also age rings?

The writer tried to ascertain the length and weight attained by the sardine at the end of a year, tracing the seasonal changes throughout it (Figs. 5, 6). In May, the small sardine caught off Mugi (The Pacific coast of Sikoku) was 6 cm in length, and that in June off Taisya (the Japan Sea coast) 5.5–6.0 cm. These small sardines reached 10 cm in August, increasing to from 11.0 cm to 12.0 cm in December. They are probably the age 0 group, its body length being almost equal to 11.5 cm (l_2) at the end of the year. In the catches in January and February, there were three different length groups, 12 cm, 15 cm, and 18 cm groups. These modal lengths resemble l_2, l_4, and l_6 respectively. The group that was 12 cm in January reached to 13–14 cm in June and July, which is equal to l_3, and the group that was 15 cm in January also reached to the 17 cm group in June and July, which is equal to l_5. Consequently, sardines less than 11.5 cm (l_2) must belong to the age 0 group, that from 11.6 cm (l_2) to 15.5 cm (l_4) to the age I group, that from 15.6 cm (l_4) to 18.0 cm (l_6) to the age

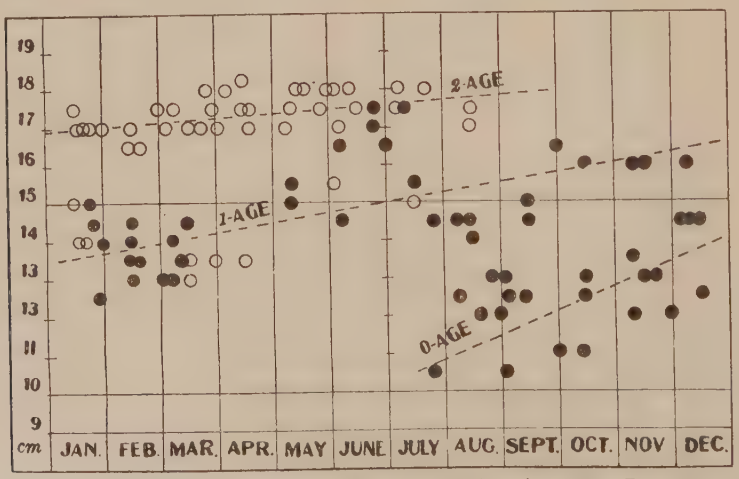

Fig. 5. Seasonal changes in body length (l cm) of the Japanese sardine (*Sardinia melanosticta*).

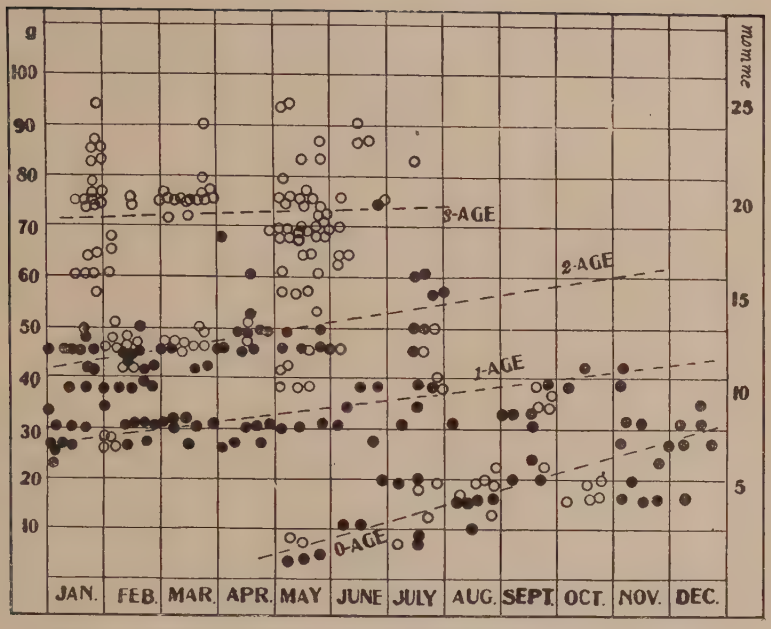

Fig. 6. Seasonal changes in body weight (w g) of the Japanese sardine (*Sardinia melanosticta*).

II group, and lastly that above 18.1 cm (l_6) to the age III group. The age IV and older age groups are rarely caught around Japan, sardines with 7 or more rings on the scale being virtually nonexistent.

Since the sardine attains a body length of l_{2n+1} in June and July (summer) and l_{2n} at the end of the year (winter), the $2n$th ring must be a winter ring and the $(2n+1)$st ring a summer ring. Among the age II group caught along the Japan Sea coast in the spring of 1938, there were no individuals with 5 rings on the scale, 1 out of 6 individuals that were examined in February, 7 out of 9 in May, and lastly 4 out of 5 in August. Those individuals with 5-ringed scales increased gradually toward summer. According to Dr. K. KISHINOUYE (1908) the small sardine that hatches out in spring attains of a total length of 13.5 cm (=11.5 cm in body length), and thenceafter increases by 3 cm and less every year. The present writer's result agrees well with Dr. KISHINOUYE's finding.

The weight of the sardine was 4–8 g in May, 10 g and more in June, 15 g in July and August, and 30 g and thereabouts in December (Fig. 6). The small sardine groups must be the age 0 group. There were also three different weight groups in the catches in January and

Table 7. Ranges in body length and weight, the conditional factor (f), and the average growth rate of each age group.

Age	Number of rings	Range of		f.	Growth rate
		body length (cm)	weight (g)		
Age 0 group	0,1	<11.5	<25	11.0	828%
Age I group	2	11.6–13.5	25–45	12.0	83%
	3	13.6–15.5			
Age II group	4	15.6–17.0	45–60	13.0	45%
	5	17.1–18.0			
Age III group	<6	<18.1	>60	>13.0	

February, namely, a group of 25 g corresponding to the age I group, a group of 45 g or slightly heavier corresponding to the age II group, and a group of 60～75 g corresponding to the age III group (Fig. 6). The ranges in body length and weight, and the average rate of growth may then be as those shown in Table 7. Following the length standard given in Table 7, we can determine the age of the sardine, the results agreeing well with the age determined from the number of rings. The sardine groups caught off Sigazima, Miyatu, and Namerikawa in January, 1938, were all of the 17 cm group, lying between l_4 and l_6, hence must belong to the age II group, although these groups also contained some age III group. Actually, 6 individuals ranging from 15.7 cm to 17.9 cm had 4 rings on scale, and those of 17.8 cm, 18.2 cm, and 18.3 cm had 6 rings. All the sardine groups caught along the Pacific coast in February, 1938, had body lengths between 13 cm and 14 cm, so that they must belong to the age I group. Both the 1st and 2nd rings, the former although indistinct, were present on the scale in these groups. The agreement just mentioned is a help in collecting a data of catches. When the average length or weight is given with the amount of catch, it is possible to know also its main age group without any laborious scale investigation.

Along the Pacific coast, usually a variety of fishing gear may be used in catching sardines of weights ranging from 30 g to 45 g during the first half of the year, and those less than 30 g during the second half, especially after September. The former is the age I group and

the latter the age 0 group. The sardines of 60 g or more that were caught from April to June must be the age II group. Of the annual yield along the Pacific coast of Honsyû, the age 0 group formed 24% and more, the age I group 54%, and the age II group 22% and less.

The old age groups increased in the catches in the Japan Sea, where the age composition of catch differed with the kind of fishing gear used. Both age II and III groups prevailed among the catches made with the gill net and drift net, and the age I group among those caught with the set net and sein, namely,

Fishing gear	age I	age II	age III
Gill net and drift net	—	25%	75%
Set net and sein net	50%	30 »	20 »

Along the west coast of Kyûsyû, the age composition of catch showed no marked difference with the fishing gear employed. The age II group prevailed most during the first half of the year, forming nearly 65% of the total, while both the age 0 and I groups dominated the second half. The age composition of the whole annual yield resembles rather the composition of that obtained along the Pacific coast of Honsyû than that from along the Japan Sea coast.

2. The Race of the sardine

Prof. I. Amemiya (1934, 1936), who studied the variation in the number of vertebral bones of the sardine, held the opinion that the average number of the vertebral bones was higher, although only very slightly, in the northern cold waters than in the southern warm waters, for which reason some local races could be expected to occur around Japan; at any rate, one in the north and another in the south. The vertebra of the sardine acquires a certain number of vertebral bones soon after hatching, which remains unchanged throughout life. Besides, since larval fish can grow more quickly in a warm region than in a cold, it follows that the more rapid the larval growth, the smaller the number of vertebral bones.

Mr. J. Nakai (1938) also investigated the variation in the number of vertebral bones, after dividing the samples examined into mature and immature groups. The immature group has no ring on the scale, while the mature groups have 1 and more rings, but, as the numbers of vertebral bones in the mature groups showed no marked difference, it was impossible to discriminate the local races by vertebral variations.

In contrast to this, in the immature group (Mr. J. Nakai examined only one sample!) the vertebral number differed markedly from the mature group from the same locality as well as from other localities. This led him to conclude that the immature group may attain a characteristic vertebral number under varying conditions in each locality, but that the vertebral number in the mature groups will be equalized, as they mingle with one another all around Japan. Mr. Nakai was also of the opinion that the Japanese sardine belong to only one race.

Dr. M. Uda and Mr. G. Okamoto (1936) believe that, based on statistics of the annual yield of sardine, there might be 4 or 5 populations along the Japan Sea coast alone. Recently, Prof. M. Tauti and Mr. Miyosi (1939), who studied the correlation between the fluctuations in the annual yield along the Japan Sea coast and those along the Pacific coast of Hokkaidô and of the Iwate and Awomori Prefectures, assumed that the sardine groups in all these localities belong to the same race, that differed, however, from the groups along the Pacific coast of Honsyû (Japan Proper).

The present writer is trying also to establish the race of sardines, based on the vertebral variation. The samples that were examined came from 44 fishing grounds around Japan and amounted to 115 samples (11000 individuals) (Fig. 7). The individuals examined were classified into different age groups, as judged by the average body lengths (see Table 7). The average number of vertebral bones was calculated for each age group for each locality, as shown in Table 8–11.

The vertebra is usually composed of 51 bones, followed in frequency by those of 50; vertebrae of 48, 49, 52, and 53 bones being rather exceptional. The maximal number of vertebral bones is 51.00 ± 0.58, and the minimal 50.13 ± 0.61. The difference of any two averages $(A_1 - A_2)$ is always much smaller than $3\sqrt{(d_1^2 + d_2^2)/2}$, where d_1 and d_2 are their standard deviations respectively. Therefore, it is obvious that the difference in vertebral numbers is inadequate for discriminating the race of sardine, and also that the immature groups show no marked difference in vertebral number from the mature groups, Mr. J. Nakai's opinion notwithstanding.

The writer, however, will further try to show that, from whatever point of view, even such slight difference as this is of significance in racial discrimination.

The mean average number of vertebral bones is calculated for each

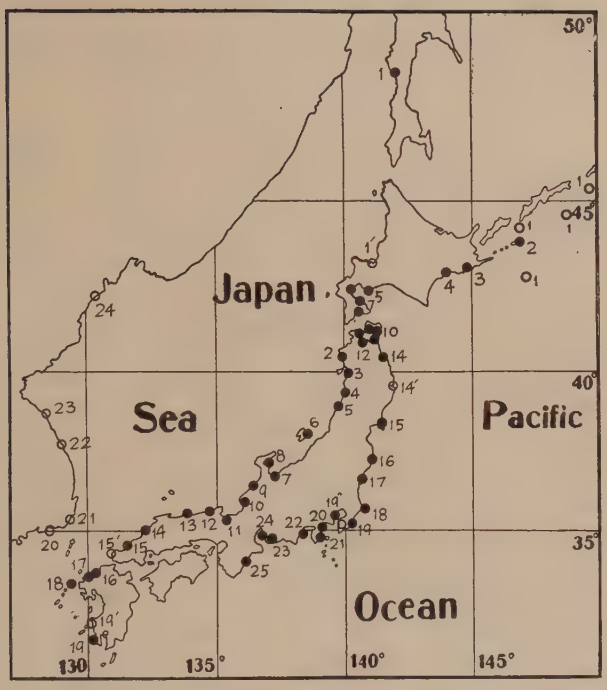

Fig. 7. Showing the Fishing grounds where the samples were collected in 1936 and 1938.

I. Amemiya, J. Nakai & H. Aikawa.

The Pacific coast.

1. Kurile Is.
2. Sikotan,
3. Akkesi,
4. Kusiro,
5. Muroran,
6. Toyoura,
7. Mori,
8. Hakodate,
9. Wakinozawa,
10. Yokohama,
11. Urata,
12. Nouti,
13. Harabetu,
14. Hatinohe,
14′. Kamaisi,
15. Siwogama,
16. Onahama,
17. Nakaminato,
18. Kuzyûkurihama,
19. Onzyûku,
19′. Tateyama
19″. Tôkyô Wan,
20. Manaduru,
21. Aziro,
22. Simidu,
23. Miya,
24. Sin-maiko,
25. Owase.

The Japan Sea coast.

1. Randomari,
2. Hukaura,
3. Tutizaki,
4. Miyanoura,
5. Kamo,
6. Ryôtu,
7. Namerikawa
8. Usetu,
9. Kanaiwa,
10. Turuga,
11. Miyatu
12. Kasumi,
13. Uratomi,
14. Hamada,
15. Senzaki,
16. Sigazima,
17. Hukuyosi,
18. Tuyosi,
19. Makurazaki,
20. Gyokuho Wan,
21. Hôgyosin,
22. Tyûmonsin,
23. Tyôzen,
24. Seisin.

age group from four main regions (Tables 12, 13). The same age groups of different year classes are very similar in their mean average vertebral numbers, although the same year classes of different age

Table 8. List of average length and weight of body, the conditional factor, the head ratio, and the number of vertebral bones.
(1. Pacific coast of Honsyû)

Age	No. of Fishing Ground	Date	Number of Individuals examined	*l* cm.	*w* g.	*f.*	*h/l*	Number of vertebral bones							
								48	49	50	51	52	53	Mean	S.D.
0-age group	a	6.14	31	7.7	5.2	11.1	0.26	—	—	—	—	—	—	—	—
	„	7.21	16	6.9	4.4	10.8	0.27	—	—	—	—	—	—	—	—
	23	7.24	63	10.3	14.1	12.9	0.30	—	—	24	36	3	—	50.67	.56
	a	7.21	6	12.9	32.1	15.0	0.26	—	—	—	—	—	—	—	—
	24*	9. 2	100	10.4	17.7	16.0	0.28	—	—	42	58	—	—	50.58	.49
	15	*9. 8	104	12.6	22.6	11.3	0.28	—	—	42	57	5	—	50.67	.57
	24	9.20	124	10.7	16.1	12.6	0.28	1	—	39	79	5	—	50.70	.58
	14	*10. 2	127	12.7	23.8	11.6	0.28	—	1	44	78	4	—	50.67	.55
	24	10.13	126	10.7	16.2	13.2	0.31	—	—	48	77	1	—	50.63	.50
	19	12.18	185	12.0	19.4	11.2	0.29	—	1	73	108	3	—	50.62	.44
I-age group	16	1.27	96	12.6	29.8	12.1	0.28	—	—	48	48	—	—	50.50	.50
	18	1.31	89	13.6	31.0	12.2	0.29	—	2	23	59	5	—	50.75	.55
	25	1.23	99	14.8	41.8	12.4	0.28	—	—	31	63	5	—	50.73	.55
	17	2.—	146	13.7	32.1	12.2	0.29	1	2	51	91	1	—	50.61	.56
	19	2.—	94	12.3	22.1	11.9	0.28	—	2	42	50	—	—	50.51	.61
	22	2.—	91	13.1	26.2	11.7	0.29	—	—	29	59	3	—	50.71	.50
	25	2.13	98	14.2	37.6	13.0	0.29	—	—	34	63	1	—	50.66	.49
	17	3. 7	140	14.2	37.8	13.0	0.29	—	—	40	98	2	—	50.73	.47
	20	3. 2	99	13.4	26.2	11.1	0.28	—	2	47	49	1	—	50.49	.56
	20	3.30	109	14.2	36.6	12.6	0.29	—	2	33	72	2	—	50.68	.53
	22	3.—	78	13.7	31.7	12.3	0.29	1	1	28	43	5	—	50.64	.68
	25	3. 1	94	12.7	31.3	11.8	0.29	—	2	31	60	1	—	50.64	.55
	25	3. 5	99	14.3	36.5	12.3	0.29	—	3	34	59	3	—	50.63	.61
	17	4. 9	100	14.5	39.1	12.8	0.29	—	—	39	59	2	—	50.63	.61
	16	5.10	99	15.0	46.2	13.8	0.29	—	—	33	62	4	—	50.71	.54
	19	5. 2	105	14.3	39.7	13.9	0.28	—	1	42	60	2	—	50.60	.55
	17	5.12	98	15.3	49.4	13.7	0.29	—	1	44	53	—	—	50.53	.52
	19	6. 6	99	13.2	30.4	13.1	0.29	—	1	31	65	2	—	50.69	.61
	15	*10. 1	109	13.2	26.1	12.4	0.29	—	—	33	72	4	—	50.73	.42
	23	11.12	110	13.6	38.8	16.8	0.27	—	—	26	81	3	—	50.79	.47
	14	*12.11	103	13.4	24.1	10.0	0.29	—	—	29	69	5	—	50.77	.52
III-age group	b	7.27	12	19.9	89.5	11.4	0.29	—	—	—	—	—	—	—	—

Note: * 1936, no mark 1938; a. Awosima (Miyagi Pref.), b. Tasirosima (do.).

Table 9. List of average length and weight of body, the conditional factor, the head ratio, and the number of vertebral bones.
(2. The Pacific coast of Hokkaidô)

Age	No. of Fishing Ground	Date	Number of Individuals examined	l cm.	w g.	f.	h/l	Number of vertebral bones						
								48	49	50	51	52	Mean	S.D.
0-age group	1	8.^{20}/$_{30}$	419	12.0	23.2	13.4	0.27	—	3	148	254	17	50.67	.55
	3	8. 9	35	12.2	25.0	13.8	0.28	—	—	—	—	—	—	—
	6	8.26	152	12.8	27.6	12.8	0.28	—	—	24	105	2	50.72	.48
	2	8.30	66	12.6	31.8	15.8	0.28	—	—	24	42	—	50.64	.48
	5	9.13	123	12.1	21.8	12.1	0.28	—	2	40	79	2	50.66	.55
	7	9. 5	232	12.1	23.0	12.8	0.27	—	—	84	146	2	50.65	.49
	11	*10.13	92	11.8	20.3	11.9	0.27	—	—	36	54	2	50.63	.53
	7	10.15	112	12.7	25.6	12.4	0.28	—	3	34	72	3	50.67	.58
	11	*11.—	81	11.6	17.2	11.0	0.27	—	5	36	34	6	50.51	.61
	7	12. 2	120	12.6	24.8	12.6	0.28	—	2	41	73	4	50.66	.56
I-age group	12	·1.26	162	14.1	33.4	11.8	0.28	—	2	53	102	5	50.68	.64
	11	·2.—	99	13.0	23.6	10.6	0.28	—	1	42	51	5	50.51	.61
	8	*7.26	123	14.7	41.3	12.6	0.29	—	1	49	66	7	50.65	.60
	9	*7.—	104	15.3	43.3	12.3	0.28	—	1	41	61	1	50.60	.53
	4	*8.15	163	14.9	46.3	13.9	0.28	—	1	48	109	5	50.72	.53
	9	*8.—	101	14.3	36.5	12.5	0.29	—	1	36	58	6	50.68	.60
	13	*8. 8	98	14.2	35.6	12.8	0.28	—	2	24	69	3	50.75	.54
	9	*9. 6	93	14.6	38.6	12.3	0.28	—	12	57	24	—	50.13	.61
	12	*9.—	100	14.3	36.6	12.8	0.28	—	2	31	67	—	50.65	.52
	5	10.15	129	16.7	38.9	13.2	0.29	—	—	47	77	5	50.67	.51
	6	10. 1	150	16.8	67.4	14.1	0.28	—	—	47	94	9	50.75	.45
	5	11.19	110	13.1	28.9	12.9	0.28	—	—	37	73	—	50.66	.47
	6	11.10	150	14.9	47.1	13.4	0.28	—	—	57	93	—	50.62	.40
	7	11. 2	97	15.4	48.6	13.1	0.29	—	—	28	66	3	50.74	.50
	5	12. 6	116	14.7	41.1	12.7	0.29	—	—	39	74	3	50.69	.52
	6	12. 9	116	14.6	40.4	13.1	0.28	—	—	46	68	2	50.62	.52
	12	*12.16	33	14.8	41.4	13.0	0.29	—	—	9	22	2	50.77	.51
II-age group	8	*6.30	51	16.9	56.6	13.5	0.29	—	1	17	33	—	50.63	.52
	9	*6.24	65	17.0	66.1	13.3	0.29	—	—	22	40	3	50.71	.55
	10	*6.24	69	17.0	64.5	13.1	0.28	—	—	14	51	4	50.86	.49
	11	*6. 6	97	16.7	59.4	13.0	0.29	—	—	25	69	3	50.77	.49
	11	*7. 9	99	17.6	67.5	12.8	0.28	1	—	32	64	2	50.67	.57
III-age group	9	*6.24	36	18.8	85.5	12.8	0.29	—	—	9	24	3	50.83	.55
	10	*6.24	33	18.5	81.5	12.5	0.28	—	—	12	21	—	50.64	.48

Note: * 1936; 1937, and no mark 1938.

Table 10. List of average length and weight of body, the conditional factor (f), the head ratio (h/l), and the number of vertebral bones (3. the Japan Sea coast).

Age	No. of Fishing Ground	Date	Number of Individuals examined	l cm.	w g.	f.	h/l	Number of vertebral bones							
								48	49	50	51	52	53	Mean	S.D.
0-age group	11	*7. 25	60	5.5	2.7	14.2	0.28	—	—	—	—	—	—	—	—
	11	*8. 10	32	6.6	4.6	15.5	0.26	—	—	—	—	—	—	—	—
	8	*8. 29	19	8.4	7.5	15.6	5.27	—	—	7	12	—	—	50.63	.54
	8	*11. 10	20	11.7	17.4	11.0	0.26	—	—	4	15	1	—	50.85	.48
	11	*12. 29	103	12.2	22.9	12.0	0.28	—	—	39	61	3	—	50.65	.54
II-age group	8	*1. —	157	14.2	22.7	10.8	0.28	—	2	48	91	16	—	50.77	.64
	11	1. 20	32	14.2	38.0	13.2	0.29	—	—	8	21	3	—	50.84	.56
	7	1. 20	33	13.7	27.4	10.6	—	—	—	12	17	4	—	50.76	.55
	8	*2. —	42	14.4	32.7	10.9	—	—	—	7	28	7	—	**51.00**	**.58**
	8	*3. —	90	14.4	28.9	10.4	0.29	—	2	22	59	7	—	50.78	.61
	8	*3. 25	63	13.5	28.4	11.7	—	—	1	23	37	2	—	50.63	.57
	8	3. 3	78	13.7	27.4	10.6	0.29	—	—	21	53	4	—	50.78	.52
	8	*4. —	111	13.5	27.7	11.3	0.28	—	—	37	70	4	—	50.70	.53
	11	4. 1	26	15.0	42.8	13.2	0.30	—	—	8	17	1	—	50.73	.52
	12	*6. —	49	14.8	41.7	12.9	0.29	—	—	16	32	1	—	50.69	.50
I-age group	8	*1. —	50	16.9	57.9	11.6	0.27	—	2	20	26	2	—	50.60	.59
	7	1. 20	61	16.8	53.8	10.8	0.28	—	1	18	39	3	—	50.72	.60
	11	1. 20	71	17.1	67.9	13.3	0.29	—	—	25	42	4	—	50.70	.57
	8	*2. —	59	17.0	54.9	11.3	0.29	2	2	9	34	11	1	50.90	.91
	7	2. 21	94	16.8	56.8	11.9	0.28	—	—	23	70	1	—	50.77	.44
	8	*3. —	25	17.0	55.4	11.1	—	—	—	7	17	1	—	50.76	.52
	8	*3. 25	36	17.2	62.1	12.4	—	—	—	16	18	2	—	50.61	.59
	10	3. 16	110	16.7	61.0	13.2	0.29	—	1	31	76	2	—	50.72	.50
	10	3. 30	112	17.2	70.3	13.6	0.29	—	—	39	68	5	—	50.70	.55
	11	3. 7	63	17.2	71.9	14.1	0.30	—	—	18	42	3	—	50.76	.53
	13	3. 22	64	17.0	62.0	13.7	0.30	—	—	19	41	4	—	50.77	.56
	8	*5. —	62	16.8	55.5	11.7	0.28	—	1	19	38	4	—	50.74	.60
	14	*5. 10	85	17.3	61.2	12.8	0.29	—	1	23	57	4	—	50.75	.55
	3	5. 26	148	17.1	70.7	13.9	0.29	—	—	43	101	4	—	50.74	.49
	6	5. 8	78	17.1	67.5	13.7	0.29	—	—	23	52	3	—	50.74	.52
	6	5. 20	50	16.7	67.2	14.4	0.30	—	—	14	32	4	—	50.80	.56
	8	5. 12	35	17.2	76.9	14.9	0.28	—	—	11	24	—	—	50.70	.46
	10	5. —	73	17.8	82.8	14.5	0.28	—	1	21	47	4	—	50.74	.58
	4	*6. 2	101	17.9	62.8	12.2	0.28	—	1	31	69	—	—	50.68	.44
	6	6. —	101	16.5	58.5	13.0	0.28	—	1	30	65	5	—	50.73	.56
	8	6. 2	98	16.4	60.8	13.7	0.29	—	1	27	67	3	—	50.74	.52
	6	6. 6	109	16.7	71.8	13.8	0.30	—	1	37	67	4	—	50.68	.56
	9	6. 2	50	16.7	69.4	14.7	0.29	—	—	15	33	2	—	50.74	.52
	10	6. 11	71	17.4	92.9	15.1	0.29	—	—	18	50	3	—	50.79	.50
	12	7. 21	40	16.6	56.6	12.5	—	—	—	15	23	2	—	50.68	.57
	2	7. 6	50	17.6	65.2	11.9	0.28	—	2	20	26	2	—	50.60	.64
	6	7. 7	105	17.2	57.7	12.9	0.28	—	—	34	70	1	—	50.69	.49
	8	*4. —	15	16.9	63.2	13.0	0.28	—	—	3	11	1	—	50.81	.50
	2	8. —	50	17.2	65.7	12.5	0.28	—	—	22	27	1	—	50.65	.53
	1	8. —	112	17.8	75.5	14.6	0.28	—	—	33	77	2	—	50.72	.49
	11	4. 1	70	16.7	69.5	13.5	0.30	—	—	18	51	1	—	50.76	.46
III-age group	11	3. 7	37	18.9	93.9	13.9	0.30	—	1	10	25	1	—	50.70	.56
	14	*5. 10	45	19.0	82.2	12.2	0.29	—	—	14	31	—	—	50.69	.46
	8	*5. —	38	18.9	83.6	12.4	0.28	—	—	8	28	2	—	50.84	.49
	8	7. 7	44	18.8	94.3	14.2	0.28	—	—	12	27	5	—	50.84	.60

Table 11. List of average length and weight of body, the conditional factor, the head ratio, and the number of vertebral bones. (4. The coast along Kyûsyû, including the Tyôsen Straits)

Age	No. of Fishing Ground	Date	Number of Individuals examined	l cm.	w g.	f.	h/l	Number of vertebral bones							
								48	49	50	51	52	53	Mean	S.D.
II-age group	15	*1.—	58	17.2	66.6	14.3	0.28	—	—	21	36	1	—	50.66	.51
	16	1.28	150	17.0	63.6	13.0	0.29	—	1	51	93	5	—	50.68	.53
	16	2. 8	120	17.2	61.0	12.4	0.29	—	—	48	68	4	—	50.63	.61
	15	2.—	96	17.0	54.3	12.9	0.29	1	2	42	50	1	—	50.50	.61
	15	*3.26	46	17.3	65.0	12.4	0.29	—	—	18	28	—	—	50.61	.49
	19	3. 4	101	17.0	58.1	11.9	0.30	—	1	32	67	1	—	50.67	.50
	19	3. 5	99	17.4	57.1	11.7	0.29	—	1	33	61	4	—	50.69	.56
	19	3.26	47	17.1	68.4	13.1	0.29	—	2	13	31	1	—	50.66	.59
	15	*4.—	62	17.1	61.2	12.1	0.29	—	—	25	35	2	—	50.63	.62
	18	*4.15	200	17.0	56.8	11.5	0.29	—	2	83	109	6	—	50.60	.60
	15	4.18	104	17.6	71.8	13.2	0.29	—	—	41	58	5	—	50.65	.55
	17	4. 6	43	17.2	71.0	13.8	0.29	—	—	16	26	1	—	50.65	.52
	17	4.18	74	16.0	72.2	13.8	0.29	—	—	26	47	1	—	50.66	.50
	17	4.24	48	17.4	74.2	14.2	0.30	—	—	15	31	2	—	50.73	.53
	15	5.30	52	17.3	57.9	12.4	0.28	—	—	14	34	4	—	50.81	.56
III-age group	15	*1.—	42	18.9	84.6	12.6	0.28	1	—	8	32	1	—	50.76	.61
	16	2.28	49	18.8	77.5	13.6	0.29	—	—	13	35	1	—	50.76	.48
	15	*3.26	54	19.1	84.2	10.8	0.29	—	—	16	35	3	—	50.76	.54
	15	4.—	35	18.5	72.9	11.7	0.29	—	—	8	26	1	—	50.80	.47
	18	*4.15	96	18.8	76.6	11.4	0.29	—	1	29	61	5	—	50.73	.57
	17	4. 6	21	18.7	87.0	13.2	0.29	—	—	6	14	1	—	50.76	.53
	17	4.18	22	18.9	90.1	13.2	0.29	—	—	7	14	1	—	50.73	.54
	15	*5.30	46	18.9	81.6	12.2	0.28	—	—	20	26	—	—	50.57	.50

Note: * 1936; no mark 1938.

groups differ considerably in number. Therefore, the effect of enviroment on the vertebral number shows no annual change, and the number of vertebral bones seems rather to be peculiar to the locality. In other words, the change in vertebral number is clearly related to age. The vertebral number increases with age among the sardine groups along the Pacific coast, that is, the vertebral number of the age 0 group is on the average 50.62 ± 0.60, that of the age I 50.66 ± 0.55, that of the age II 50.71 ± 0.55, and that of the age III 50.75 ± 0.52 along the

Table 12. List of average number of vertebral bones of each age group along the Pacific coast.

		Year		Number of vertebral bones							
		Class	Investigated in	48	49	50	51	52	53	Mean	S.D.
Off Hokkaidô (including the Tugaru Straits)	0	1936	1936	—	3	83	102	11	1	50.62	.61
		1938	1938	—	—	8	13	—	—	50.62	.49
		Mean		—	3	91	115	11	1	50.62	.60
	I	1935	1936	—	22	345	567	24	—	50.64	.58
		1936	1937	—	3	411	719	27	—	50.66	.52
		1937	1938	—	3	95	153	10	—	50.65	.57
		Mean		—	28	851	1439	61	—	50.64	.55
	II	1934	1936	—	3	130	262	16	—	50.71	.57
		1936	1938	—	—	88	164	10	—	50.70	.53
		Mean		—	3	218	426	26	—	50.71	.55
	III	1933	1936	—	—	35	87	4	—	50.75	.51
		1935	1938	—	—	9	17	2	—	50.75	.60
		Mean		—	—	44	104	6	—	50.75	.52
Off Honsyû	0	1936	1936	—	1	73	108	3	—	30.62	.53
		1938	1938	—	—	149	234	8	—	50.64	.52
		Mean		—	1	222	342	11	—	50.63	.52
	I	1935	1936	—	1	115	204	14	—	50.69	.57
		1937	1938	2	19	643	1142	38	—	50.65	.55
		Mean		2	20	758	1346	52	—	50.65	.55

Pacific coast of Hokkaidô, while that of the age 0 is 50.63 ± 0.52 and that of the age I 50.65 ± 0.55 along the Pacific coast of Honsyû (Table 12). The mean average number of all age groups is 50.66 ± 0.55. The average number of the age 0 and I groups is smaller than the mean, while those of the age II and III groups are higher.

In the Japan Sea, the average vertebral number of the age I groups is 50.75 ± 0.59, that of the age II 50.73 ± 0.54, and that of the age III 50.71 ± 0.58. The average number of each group decreases with age, contrary to the trend shown by sardines in the Pacific region. The average number of the age I group is higher than the mean average number (50.73 ± 0.56), that of the age II is nearly similar to it, while that of the age III group is smaller.

Table 13. List of average number of vertebral bones of each age group along the coasts of the Japan Sea and Kyûsyû, in 1936 and 1938.

	Year			Number of vertebral bones							
	Age	class	investigated in	48	49	50	51	52	53	Mean	S.D.
The Japan Sea	0	1936	1936	—	—	19	38	—	—	50.67	.52
	I	1935	1936	—	6	202	382	42	—	50.73	.59
		1936	1938	—	—	53	117	13	—	50.78	.56
		Mean		—	6	255	499	55	—	50.75	.59
	II	1934	1936	2	7	221	464	38	—	50.72	.59
		1936	1938	—	5	364	812	42	—	50.73	.52
		Mean		2	12	585	1276	80	—	50.73	.54
	III	1933	1936	1	1	68	121	8	—	50.67	.58
		1935	1938	—	—	39	95	5	—	50.75	.51
		Mean		1	1	107	216	13	—	50.71	.58
Off Kyûsyû	II	1934	1936	—	2	161	208	13	—	50.60	.56
		1936	1938	1	6	289	489	21	—	50.65	.56
		Mean		1	8	450	697	34	—	50.63	.55
	III	1933	1936	—	2	81	180	10	—	50.72	.57
		1935	1938	—	1	44	103	7	—	50.75	.55
		Mean		—	3	125	283	17	—	50.73	.54

The mean number of vertebral bones of sardine groups in the Japan Sea and in the Pacific region is **50.70±0.55**. The mean vertebral numbers of all age groups in the Japan Sea exceed 50.70; they are generally smaller than this in the Pacific region. Therefore, the group that shows an average vertebral number smaller than 50.70 will be called here the "*Pacific race* or *group*," and the group higher than 50.70 in vertebral number the "*Japan Sea race* or *group*." In the whole of the Pacific coast, there were 16 *Pacific groups* in the 18 age 0 groups, 28 in the 40 age I groups, 2 in the 5 age II groups, and 1 in the 2 age III groups. The Pacific group forms 65% (average) of the total (Table 8, 9). The increase in the average vertebral number with age seems to be due mainly to decrease in the *Pacific groups* in each age group on the one hand and to the increase in the *Japan Sea groups* on the other.

The age 0 group in the Japan Sea was not examined with sufficient frequency to enable an accurate determination of its average vertebral number and also the composition of both the *Japan Sea* and the *Pacific groups*. There were 11 *Japan Sea groups* in the 13 age I groups, 25 in the 33 age II groups, and 6 in the 13 age III groups in the Japan Sea (Table 10). The Japan Sea groups form 67% (average) of the total here. In the age 0 and I groups, there is a distinct difference in the compositions of both the *Pacific* and the *Japan Sea races* between the Pacific and the Japan Sea regions. Thenceafter, the difference in composition becomes only slight, both races mingling even in equal proportion among the age III group throughout whole regions. Consequently, mixing of the *Pacific* and the *Japan Sea races* gradually takes place with the age of sardine.

The final problem is whether or not the *Japan Sea race* is really entirely different as a race from the *Pacific race*. The writer regards them as different races for the following reasons. Whereas the *Pacific race* is composed mainly of the age 0 and I groups, and their vertebral number is less than 50.70, the *Japan Sea race* is composed of all age groups, of which the age II and age III groups are fairly preponderent; its vertebral number is, moreover, higher than 50.70.

Mr. J. Nakai, who studied the quantity and the distribution of the pelagic eggs of the sardine, concluded that the main spawning ground is the neritic region off the west coast of Kyûsyû. The number of eggs spawned here, compared with that in any other locality, is enormous, so much so that all the sardine groups around Japan can receive recruits only from here. Consequently, they must be considered as belonging to the same population, as pointed out by Fr. Heincke.

The rate of the group maturity is expressed here by the percentage of individuals possessing gonads or testis heavier than 1 g, since the eggs are visible to the naked eye in gonads heavier than this (N. Sako, 1938). The maximum rate of group maturity of the age I group is 40% in March, that of the age II group 90% in February, and that of the age III group 99% also in February. The considerably high rate of group maturity lasts longer in the old age group than in the young, and appears earlier in the south than in the north. Comparing the maximal rate with the amount of catch, it is believed that the eggs spawned must also be considerable in the various localities, except off Kyûsyû, since the annual yield of "Sirasu" (larval sardine less than 3 or 4 cm in length) and also of the young sardine along the

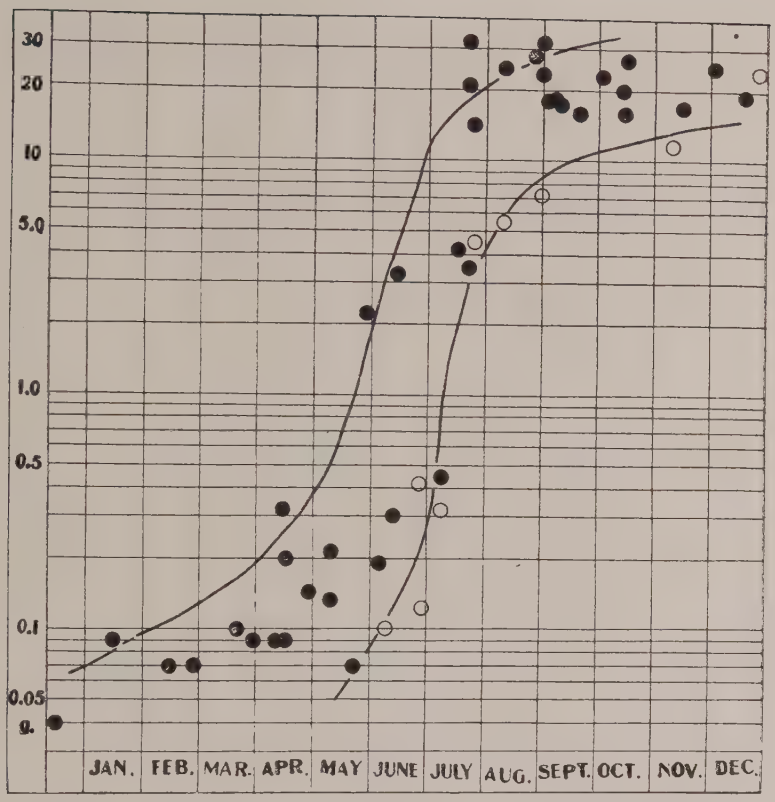

Fig. 8. Seasonal changes in body weight (w g.) of the age 0 sardine.

Pacific coast south of Sagami Bay is never smaller than that off the west coast of Kyûsyû. Consequently, the sardine group can receive recruits not only from off Kyûsyû, but also from the southern region of the Pacific coast and of the Japan Sea. The sardine groups must be considered quite separate from their spawning grounds. Whereas the *Sirasu* appears earlier in the Pacific region than in the Japan Sea (Fig. 8), the pigment develops earlier in the *Sirasu* of the Japan Sea than in that of the Pacific region (Fig. 9). In this way, a number of racial differences can also be found between the *Pacific* and the *Japan Sea races.*

3. The migration of the sardine

The main migratory routes of the Japanese sardine are four (Fig. 10), as Dr. A. G. Kaganowsky (1932) supposed. Generally

Fig. 9. Differences in pigment development of larval sardines along the Pacific and those along the Japan Sea coasts; (right). Larval sardines along the Pacific coast (off Yosida, Sizuoka Prefecture; May 10, 1937), (left) same along the Japan Sea coast (off Hinomisaki, Simane Prefecture, June 27, 1936).

speaking, the sardine migrates northward along these routes during the first half of the year and then returns south during the second half. There are two routes in the Pacific region, the one, the neritic route (1) and the other, the oceanic Kurosiwo route (2). Along the neritic route, the age I group moves northward from March and April, most of it arriving off Hokkaidô in July. Some of the age 0 group also migrates northward after summer, appearing also off Hokkaidô, after which they turn south in the autumn. Since the sardine group caught along the Pacific coast of Honsyû is generally the age 0 group in autumn and winter, the most of the age I group never return off Honsyû. Judging from the seasonal changes in the catches in the Tugaru Strait, the age I group migrates into the Japan Sea through

Fig. 10. The main migratory routes of the Japanese sardine around Japan. 1: the neritic route; 2: the oceanic Kurosiwo route; 3: the Tusima current route; 4: the Liman current route.

the strait. The catch of the Pacific group of age I group increased from July to October, while the Pacific group of the age 0 prevailed after November and also in January and February of the following year (Table 14). Since, in this way, the Pacific groups older than the age I group become scarce along the Pacific coast of Honsyû, the neritic route is useful for the northward migration of the age I group on the one hand and for the northward and southward migrations of the age 0 group on the other.

An age 0 group, that had already attained to 12 cm (20 g) in August, was caught in a number of fishing grounds along the Pacific coast of Hokkaidô. This well grown group, exceeding a body length of l_2, which seemed to belong to the age I group, had only one ring

Table 14. Seasonal changes in the age composition of catches in the Tugaru Straits, in 1936.

No.	Fish. Ground	Date	Age-composition				Vert. Number	
			0 %	I %	II %	III %	Mean	S.D.
9	Wakinozawa	6. 24			64.0	36.0	50.75	.55
10	Yokohama	6. 24			66.7	33.2	50.78	.50
11	Urata	6. 6		12.4	82.4	5.2	50.77	.49
8	Hakodate	6. 30		9.8	70.6	19.6	50.63	.52
11	Urata	7. 9		2.0	31.3	66.7	50.67	.57
9	Wakinozawa	8. —		73.3	26.7	—	50.60	.53
8	Hakodate	7. 26		85.2	14.8	—	50.65	.60
9	Wakinozawa	8. —		97.1	2.9	—	50.68	.60
13	Harabetu	8. 8		98.0	2.0	—	50.75	.54
9	Wakinozawa	9. —	2.2	87.7	10.1	—	50.13	.61
12	Nouti	9. —	—	98.9	1.1	—	50.65	.52
11	Urata	10. 13	72.6	27.4	—	—	50.63	.53
11	Urata	11. —	96.5	3.5	—	—	50.51	.61
12	Nouti	12. 16	93.9	6.1	—	—	50.77	.52
12	Nouti (1937)	1. 26	—	96.3	3.7	—	50.68	.67
11	Urata (1937)	2. —	—	98.0	2.0	—	50.51	.61

Table 15. The fishing grounds of the oceanic 0-aged group west of the Kurile Islands in the summer of 1938.

St.	Position		Date	Temperature			Catch	
	E. Long	N. Lat		0 m	25 m	50 m	skipper	sardine
29	151°38′	43°09′	8. 16	13.7	10.6	2.8	1	—
32	146°40′	44°16′	8. 16	16.4	3.8	1.9	17	13
33	146°40′	44°30′	8. 17	14.0	9.0	3.4	27	3
37	150°02′	45°25′	8. 20	8.7	6.9	3.7	235	24
40	153°33′	46°00′	8. 21	10.8	5.9	2.3	55	4
43	153°51′	46°48′	8. 22	12.2	11.9	3.7	33	548
47	157°10′	50°04′	8. 24	11.2	9.1	1.9	73	1
56	152°24′	46°32′	8. 29	13.8	11.7	4.3	abundant	500
57	151°44′	46°03′	8. 30	8.8	6.4	3.8	abundant	300
61	148°51′	44°32′	8. 31	10.5	5.6	2.7	—	—
70	147°04′	43°48′	9. 4	17.4	12.3	9.1	9	1

(r_1) on the scale. Although this group differed greatly from the age 0 group found along the Pacific coast of Honsyû, it resembled the oceanic group caught far west of the Kurile Islands (Table 15). This oceanic group was caught in the sea just north of the polar front, where the sea was densely crowded with plankton, much more so than off Honsyû at the time (H. Aikawa, 1938). It must have belonged to the *Pacific race*, as its average vertebral number was 50.65 ± 0.55, although this is a little too large for an age 0 group of the *Pacific*. This oceanic group might have come here as larva or as young sardine, carried by the Kurosiwo current, seeing that in the summer of 1934, the larva of *Engraulis japonicus* (T. and S.) could be collected in great abundance in the Kurosiwo far away from land, and that the small sardines were found often in the stomach of the bonito caught in the Kurosiwo in the summer in this neighbourhood. The larva or young sardine, finding here a suitable nursing ground, grew more rapidly than the age 0 group in the neritic region, probably arriving off Hokkaidô after summer and migrating southward with the neritic age 0 group. As a matter of fact we found this well grown age 0 group among the catches made off both Hatinohe and Siwogama in the autumn of 1936, whence it follows that the oceanic Kurosiwo route is suitable for the northward migration of the small age 0 group during the first half of the year.

At the same time, the Japan Sea groups of the age II and III groups migrated from the Japan Sea through the Tugaru Strait in the Pacific region of Hokkaidô and also into the northern part of Honsyû (off Awomori and Iwate Prefectures). The *Japan Sea race* must exceed in amount the *Pacific race* in these localities, because the fluctuation in the annual yield here, as Prof. Tauti noticed, correlates well with that of the Japan Sea. The average vertebral number higher than 50.70 was obtained for the old age groups caught in the Tugaru Strait in spring, when the *Japan Sea* group is believed to migrate here (Table 14).

There are also two migratory routes in the Japan Sea; that is, the one along the east coast of Tyôsen and along the Siberia (the Liman current route, 4) and the other along the coast of Honsyû (the Tusima current route, 3). These two routes unite in the north, off Saghalin, and also in the south in the Tyôsen Strait, whence the route extends southward along the coast of Kyûsyû, although, contrary to Dr. A. G. Kaganowsky's opinion, it will never reach the Liu-Kiu

Islands. Judging from the shift of the fishing grounds, both the age II and III groups migrate northward along these two routes from spring to sumemr, whence they may turn south. These two age groups, which are again observed in the southern Japan Sea in December, migrate southward and appear off Kyûsyû through the Tyôsen Strait. These old age groups appear also off the Okhotsk coast of Hokkaidô in summer, and resemble in age composition, and in both length and weight frequencies those caught off the Pacific coast of Hokkaidô in summer as before mentioned.

The age composition of catches along the west coast of Kyûsyû greatly resembles, as already pointed out, that of the Pacific region rather than that along the Japan Sea coast. The average vertebral number of the age II group is 50.63 ± 0.55, while that of the age III group is 50.73 ± 0.54 (Table 11). According to other invetsigators, there were 13 *Pacific groups* out of the 15 age II groups, and in contrast to it, 7 *Japan Sea groups* out of the 8 age III groups along the coast of Kyûsyû. According to the data of Prof. Amemiya and Mr. Nakai, there were also 7 *Pacific groups* among 11 mature groups here. Therefore, the *Pacific groups* of the vertebral number less than 50.70 were prevalent more than the *Japan Sea groups* along the coast of Kyûsyû.

There were also observed 6 *Pacific groups* out of 9 mature groups along the east coast of Tyôsen, while the *Pacific groups* formed only 33% of all the groups examined in the Japan Sea on an average. Therefore, the *Pacific groups* decreased gradually northward in the Japan Sea, where they never reach very far north. On the other hand, the *Japan Sea groups*, which appeared off Kyûsyû, were mostly the age III group and were rather smaller in amount than the younger groups of the *Pacific race*. In the Japan Sea, the age I group is usually caught throughout the year and the age 0 group after summer. They may be resident, showing no distinct migration, differing in this respect from these age groups of the Pacific region.

Résumé

(1) The age of the Japanese sardine, *Sardinia melanosticta* (T. and S.) is determined based on the rings that are formed on the scale. It forms two rings every year. The oldest individual has 6 rings on the scale in spring, although the 1st ring becomes incomplete and inconspicuous, especially after the 2nd ring is completed. Individuals

with 7 and more rings on the scale are rather scarce among the catches around Japan.

(2) As the length of the covered portion of the scale (T mm) grows in a definite ratio to the body length (l cm) and the radii of the rings show no marked variation, the body length (l_n cm), when the nth ring is completed, is computed from the radius of the nth ring (r_n mm). Thus, the range in the body length of each age group is as follows; The age 0 group is less than 11.5 cm (l_2 cm), the age I group from 11.5 cm to 15.5 cm (l_4 cm), the age II group from 15.6 cm to 18.0 cm (l_6 cm), and the age III group greater than 18.1 cm. (l_6 cm).

(3) There are two races of the sardine around Japan. The *Pacific race* is mainly composed of the age 0 and I groups and the vertebral number is less than 50.70. The *Japan Sea* race is composed of all age groups, its vertebral number being greater than 50.70. The race of the Pacific region, which differs distinctly from the *Japan Sea race* during the 0- and I-stages of age, generally lives along the Pacific coast. The age I group of the *Pacific race* migrates into the Japan Sea through the Tugaru Strait after the second half of the year, and only a few return off Honsyû. On the other hand, the age II group of the *Pacific race* enters the southern Japan Sea from the west coast of Kyûsyû through the Tyôsen Strait during the first half of the year.

(4) The age II and III groups of the *Japan Sea race* appear off the northern coast of the Pacific region in summer through the Tugaru Strait, whereas they arrive off Kyûsyû in winter through the Tyôsen Strait.

(5) The mixing of these two races usually occurs off the northern part of the Pacific coast in summer on the one hand and off Kyûsyû in winter on the other. Moreover, the mixing takes place gradually, judging from the changes with age in the average number of the vertebral bones.

(6) The average number of the vertebral bones must be higher in the north than in the south, due to the fact that the *Japan Sea race* appears in the north in summer along the Pacific coast, while in spring the *Pacific race* is dominant in the south in the Japan Sea.

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Observations on Some Beaches of Japan and Their Molluscan Fauna*

By

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The object of the present article is to describe the observations made on some beaches of Japan with the purpose to find, if possible, the relation existing between type of beach and the molluscan fauna scattered on it, and to classify as far as possible the types of beach according to topography as well as molluscan fauna. Further, it is hoped that observations on various beaches will result in faciliating certain problems in geology.

As the first attempt to the above mentioned questions, the writer has written this article, and it is only with the increase in the number of observations that a possible solution may be found. In this article, he merely describes the observations on certain beaches, and leaves concluding remarks for a future opportunity.

Before going further the writer wishes to record his deep appreciation to Prof. Hisakatsu Yabe of the Institute of Geology and Palaeontology, Tôhoku Imperial University, Sendai, for kindly looking over and correcting this article before publication.

Beach of Hisanohama, Iwaki

The beach of Hisanohama, Iwaki faces the Pacific Ocean and is of the open sea type. It is about a little more than two miles long, provided at its northern part by a small rocky promontory of steep cliffs and from the sea-ward end of this promontory, a rocky bar extends nearly parallel for a distance of some 500 meters or thereabout, the maximum distance from the shore being about 300 meters. This rocky bar forms a sort of a wave-protection for the intermediate area.

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* This is the first note to "Observations on Some Beaches of Japan," and others are expected to be published at irregular intervals.

From the promontory to the southern end of the beach is found only fine pebbles at the strand line, and fine sand without pebbles on the beach. At the southern end of the beach is another promontory, and in the area between the promontories are found a number of small rocks exposing only their tops.

The beach-slope of Hisanohama is rather steep and the waves at the time of visit were very high, probably about 10 feet at the strand line. At the northern part of the beach, the waves are weakened by the rocky bar, and due either to the prevailing wind at the time of observation or to the topographic features of the northern part of the beach, the waves attack the coast from the northeast direction, while elsewhere they hit the coast-line from the east or southeast. The pebbly beach contained besides sand, some fragments of shells.

The molluscan shells are very rare along this beach and only *Mytilus crassitesta* LISCHKE was sporadically observed, and isolated valves of water-worn *Spondylus cruentus* LISCHKE were rarely seen. Furthermore, shells of the former were found only at the northern half of the beach; thus they were either brought to their resting place by the prevailing winds and wave action from the rocky cliffs at the northern part of the beach or from the rocky bar offing the strand-line. Probably the waves are too strong in this region for shells that live burried shallowly in sand or mud to thrive; possibly the shells live further out to sea where the wave action has not direct influence on them. Thus it appears that there is no strong under-current in this region strong enough to bring shallowly burried shells offing the shore to the strand line.

A great effort to collection of shells resulted in the following species.

Arca obtusoides NYST
Cardita variegata BRUGUIERE
Chama aspera REEVE
Corbicula sandaiformis YOKOYAMA
Coptothyris grayi DAVIDSON
Gastrana yantaiensis CROSSE & DEBEAUX
Hiatella arctica LINNÉ
Iris mitis DESHAYES
Meretrix meretrix LINNÉ
Mytilus crassitesta LISCHKE
Mactra crossei DUNKER
Batillaria cumingi CROSSE
Diadora elaborata SOWERBY
Ostrea nippona SEKI
Paphia philippinarum ADAMS & REEVE
Protothaca jedoensis LISCHKE
Pecten irregularis SOWERBY
Petricola acquistriata SOWERBY
Pholadidea penita CONRAD
Saxidomus purpuratus SOWERBY
Spondylus cruentus LISCHKE
Pseudogrammatodon dalli SMITH
Volsella auriculata KRAUSS
Acmaea pygmaea DUNKER
Acmaea pallida GOULD
Terebra chibana YOKOYAMA

Polinices didymus Bolten
Nucella freycincti Deshayes
Lemintina imbricata Dunker
Thais luteostoma Dillwyn
Tugalia decussata A. Adams
Tegula pfeifferi Philippi
Tegula basilirata Pilsbry
Umbonium giganteum Lesson

The above list of shells although very small in number of species and in individuals, readily shows that, 1) most of these species are rock-inhabiting forms, 2) sand or mud burrowing forms are hardly represented, 3) rock-boring forms are rare, and as a result it is noticed that, 1) the rock inhabiting species were brought to the beach by the agency of prevailing winds and currents, 2) the mud or sand burrowing forms were brought to the beach probably by under-currents, and 3) all of the shells were carried from their original place of habit to the place from where they were collected by wind action, current action and that shifting of the sand and pebbles after their being brought to the beach may have caused their worn aspect.

Beach of Nagahama, Rikuzen

The beach of Nagahama, Rikuzen is quite free from muddy materials and rocky shores and consists of sand. The sea chart published by the Hydrographic Department of the Imperial Japanese Navy shows that the adjacent sea is a very shallow one and is provided with a very gently sloping sea bottom. Sand continues to a depth of some 30–45 meters before gradually merging into muddy materials at a distance of about two miles from the strand-line. Beyond the depth of 35–40 meters the sea bottom becomes rocky. Since no small rivers empty into this sand beach, and since it is free from muddy or rocky materials, the molluscan fauna is but a small one. The geographic distribution, however, of certain species have been extended. The total number of species collected from the beach of Nagahama is as follows.

Anomia cytaeum Gray
Arca boucardi Jousseume
Arca inflata Reeve
Arca subcrenata Lischke
Barnea dilatata Souleyet
Clementia vatheleti Mabille
Cyclina sinensis Gmelin
Dosinia japonica Reeve
Macoma incongrua v. Martens
Macoma tokyoensis Makiyama
Volsella modiola Linné
Yoldia notabilis Yokoyama
Acmaea pallida Gould
Argobuccinum oregonensis Redfield
Epitonium acuminatum Sowerby
Haliotis kamtchatkana Jonas
Littorina brevicula Philippi
Monodonta labio Linné
Nassarius festivus Powys
Turbo coreensis Recluz

Macoma secta Conrad
Macoma vestaloides Yokoyama
Mactra sachalinensis Schrenck
Mactra sulcataria Reeve
Mactra veneriformis Reeve
Mya arenaria Linné
Meretrix meretrix Linné
Paphia philippinarum Adams & Reeve
Protothaca adamsi Reeve
Protothaca jedoensis Lischke
Ostrea gigas Thunberg
Pecten nipponensis Kuroda
Raeta magnifica Yokoyama
Raeta yokohamensis Pilsbry
Sanguinolaria olivacea Jay
Septifer virgatus Weigmann
Tegula basilirata Pilsbry
Tegula rustica Gmelin
Olivella fulgurata Adams & Reeve
Purpura burnetti Adams & Reeve
Polinices didymus Bolten
Thais luteostoma Dillwyn
Tritonalia japonica Dunker
Umbonium moniliferum Lamarck
Lingula unguis Linné
Balanus rosa Pilsbry
Astrerias versicolor Sladen
Echinarachnius mirabilis Agassiz
Strongylocentrotus pulcherinus Agassiz
Ganesella sp. indet.
Thiara libertina Gould
Viviparus malleatus Reeve

Besides the molluscan shells collected from Nagahama, the brachiopods and other animals are also listed above. In addition to the molluscan shells mentioned above, the following also occur.

Siliqua pulchella Dunker
Solen gouldii Conrad
Tellina iridella Martens
Taras ustus Gould
Solecurtus divaricatus Lischke
Solen krusensterni Schrenck
Tellina nitidula Dunker
Volsella hanleyei Dunker

From the above list is noticed that there are a number of rocky-inhabiting species intermingled among the sand-inhabiting forms. True brackish-water types are not found, unless *Cyclina sinensis* is considered to be one of that kind. The presence of land and fresh-water shells is also worthy of mention. The rock-inhabiting species were all collected from about 300 meters or slightly more from the eastern part of the beach where are found rocky shores. Prevailing wind and currents seem to be responsible for their presence on the sand beach where they do not normally live. The mud-inhabiting species are represented but by isolated or single specimens, thus showing that the habitat was not favorable to their thriving. The fresh-water and land shells were probably brought down to the sea by the Kitakami-gawa (river), to be later brought to the beach by wind and wave (current) action.

The present beach is a good example of W. H. Twenhofel's[1] statement that. "In any consideration of the environments of

1) W. H. Twenhofel: Environment in Sedimentation and Stratigraphy.

organisms, four phases of the individual organic history must be considered. These are the environments in which the organisms lived, the environments in which they died, the environments in which the dead bodies and appendages endured after death, and the environments in which the preservable remains were entombed."

Thus it is found that the presence of rock-inhabiting species strewn on the sand beach far from their original habitat is a good example. Consequently, the first phase of the rock-inhabiting species was the rocky shore about 300 meters or more from their point of discovery, the second phase was probably the shallow water adjacent to the rocky-shores, and the third phase is where they were found, or the sand beach. Assuming the fourth phase would be found, it would probably be in the sand beach, when raised would become a sandstone.

Beaches of Oga Peninsula, Ugo

The recent mollusca strewn along the coast line of Oga Peninsula, Ugo, one of the largest land-arms extending into the Japan Sea, were collected with the view to study their distribution in regard to beaches. The collecting localities are, 1) between Wakimoto at the east and Tubaki at the west, and, 2) from Hamaguti at the west to Anden at the east; the former is on the southern side of the Peninsula while the latter is on the northern. The species collected are but few in number but comparatively large in individual numbers.

Along the northern shores of the Peninsula, the tidal zone is a narrow one and since the material consists largely of pebbles, boulders with little sand stretches, the fauna inhabiting there is poor in species but rich in individuals. Further, in certain or many of the regions of this coast-line the bottom near shore consists of the bed-rock of the Neogene sediments. Characteristic along this beach is the large number of specimens of *Glycymeris albolineatus* Lischke and *Phalium strigatum* Reeve. Probably the narrow coast line provided with cliffs and coarse material does not favor the flourishing of minute forms of molluscs, species with a thin shell or sessile forms, and only those provided with a thick shell were found.

The sea coast of Wakimotó is covered with algae to such an extent

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that collection of recent mollusca is made difficult. Although the beach is a sandy one and moderately broad, the marine algae about 7 meters in width and nearly two feet in thickness at least acts as a barrier to little shells as well as to large ones.

The coast of the southern part of the Peninsula was generally covered with marine algae wherever the conditions were favorable to its growth. The probable cause for the large accumulation of marine algae on the southern coast may be due to in part, the winds which continually came from the south during a considerable period of time. During this prevailing wind, fishing is said to be bad. This region is also known for its large output of sea-grasses. From the region between Hunakawa and Tubaki marine shells were rich in individual number and species at places where the conditions were favorable. Elsewhere they are rarely found. The coast-line topography seems to be one of the important factors controlling the beaches of this Peninsula.

The northern coast line of Oga Peninsula is a smooth one having no irregularities or indentations worthy of mention, however, it is provided with low cliffs of considerable extension. The western coast which extends from Iridosaki at the northwest to Siose-saki at the southwest is rich in indentations and many small islets are found bordering the coast-line, making a very beautiful sight to the eye. A large crater-bay, Tonga-wan is one of the interesting features of this coast-line. Indentations are well developed in the regions between Siose-saki and Nanpei-sawa; here also are found many small islets. The southern coast-line extends from Siose-saki to the entrance of the bay of Hatirogata. From Nanpei-sawa to the entrance of the bay of Hatirogata, the coast-line is a very simple one, and cliffs are found only in a short distance between Wakimoto at the east to Hadati at the west.

The coast-line topography is quite in accord with the material comprising the beaches of the Peninsula, and the kind of molluscs found inhabiting there are in good agreement with the materials.

In many blocks of the Wakimoto sandy shale found strewn on the shores on the coast of Wakimoto, the type locality of the Wakimoto beds, many boring shells were found piercing the soft sandy shales. This feature was not observed at Onagawa, where are developed the Onagawa siliceous shale beds, probably owing to the hard nature of the rock. The majority of the boring shells were found to be still

alive, and are probably exposed to air during tides.

That the oceanic currents affecting the beaches of this Peninsula is readily seen from the distribution of the molluscan shells can be noticed by the fact that the following few species which occur on the northern coast were not collected from the southern one, namely, *Acila insignis* GOULD, *Astarte alaskensis* DALL, *Dosinia japonica* REEVE, *Meretrix meretrix* LINNÉ, *Pecten yessoensis* JAY, *Tellina venulosa* SCHRENCK, *Venus stimpsoni* GOULD, *Haliotis kamtchatkana* JONAS, and a number of others. Found on the southern coast but not on the northern one are such species as, *Chama semipurpurata* LISCHKE, *Mytilus crassitesta* LISCHKE, and a large number of others. Besides oceanic currents it is also evident that bottom control plays the largest role in their distributions in such a small area as a single Peninsula.

The species collected between Wakimoto to Tubaki on the southern coast are given below.

Aloides venustus GOULD
Arca boucardi JOUSSEAUME
Barnea fragilis SOWERBY
Corbicula leana PRIME
Cardita cumingiana DUNKER
Gastrana yantaiensis CROSSE & DEBEAUX
Lucina pisidium DUNKER
Mytilus crassitesta LISCHKE
Paphia philippinarum ADAMS & REEVE
Petricola mirabilis DESHAYES
Pseudochama retroversa LISCHKE
Ostrea circumpicta PILSBRY
Septifer keenae NOMURA
Solen gouldii CONRAD
Volsella auriculata KRAUSS
Coptothyris grayi DAVIDSON
Acmaea grata GOULD
Acmaea pallida GOULD
Batillaria multiformis LISCHKE
Cerithium kobelti DUNKER
Cellana eucosmia PILSBRY
Hemifusus ternatanus GMELIN
Hipponyx conicus SCHUMACHER
Littorina millegrana PHILIPPI
Monodonta labio LINNÉ
Nassarius festivus POWYS
Nassarius livescens PHILIPPI
Oliva mustelliana LAMARCK
Pseudoliotia micans ADAMS
Anomia cytaeum GRAY
Arca subcrenata LISCHKE
Botula californiensis PHILIPPI
Chama semipurpurata LISCHKE
Gastrana japonica MARTENS
Iris mitis DESHAYES
Macoma incongrua v. MARTENS
Mactra sulcataria DESHAYES
Pecten laqueatus SOWERBY
Protothaca jedoensis LISCHKE
Ostrea gigas THUNBERG
Spondylus cruentus LISCHKE
Septifer virgatus WEIGMANN
Tellina iridella MARTENS
Zirphaea constricta SOWERBY
Siphonodentalium ozawai YOKOYAMA
Acmaea saccharina LINNÉ
Batillaria cumingi CROSSE
Babylonia japonica REEVE
Cellana toreuma REEVE
Cypraea japonica SCHILDER
Homalopoma sangarense SCHRENCK
Gibbula callichroa PHILIPPI
Lementina imbricata DUNKER
Mitrella varians SOWERBY
Nassarius dominulus TAPP.-CANTERI
Nassarius hypolius PILSBRY
Polinices didymus BOLTEN
Pyramidella pulchella ADAMS

Tegula pferifferi PHILIPPI
Tegula rustica GMELIN
Thais clavigera KÜSTER
Tritonalia japonica DUNKER
Turbo coronatus SOLANDER
Umbonium moniliferum LAMARCK
Tegula umbilicata LISCHKE
Triphora tricincta DUNKER
Thais bronni DUNKER
Turbo coreensis RECLUZ
Umbonium costatum VALCIENNES
Vexillum hizenensis PILSBRY

From the northern coast, or from Hamaguti to Anden, the following species were collected, namely.

Arca granosa LINNÉ
Acila insignis GOULD
Dosinia japonica REEVE
Glycymeris yessoensis SOWERBY
Gomphina melanaegis RÖMER
Meretrix meretrix LINNÉ
Mactra sulcataria DESHAYES
Pecten laqueatus SOWERBY
Petricola aequistriata SOWERBY
Solecurtus divaricatus LISCHKE
Tellina venulosa SCHRENCK
Acmaea pallida GOULD
Cerithium kochi PHILIPPI
Fusinus perplexus ADAMS
Oliva irisans LAMARCK
Phalium strigatum GMELIN
Semisulcospira libertina GOULD
Tympanotonus cingulatus DUNKER
Umbonium moniliferum LAMARCK
Arca subcrenata LISCHKE
Astarte alaskensis DALL
Gastrana japonica MARTENS
Glycymeris albolineatus LISCHKE
Iris mitis DESHAYES
Macrocallista pacifica DILLWYN
Mactra sachalinensis SCHRENCK
Pecten yessoensis JAY
Ostrea gigas THUNBERG
Sanguinolaria olivacea JAY
Venus stimpsoni GOULD
Cancellaria nodulifera LAMARCK
Cerithium cingulatum DUNKER
Haliotis kamtschatkana JONAS
Olivella fortunei ADAMS
Polinices didymus BOLTEN
Terebra awajiensis PILSBRY
Turritella fortilirata SOWERBY

Although the collection can not be said to be a complete one, yet characteristic ones were collected, from which it may be deduced that the molluscan fauna of both the northern and southern shores of the Peninsula are not the same. The differences in the fauna can be explained by several ways among which the following few are outstanding features, namely, 1) bottom control, 2) coast-line topography, 3) strength of attacking waves, 4) prevailing winds, 5) breadth and depth of the coasts. Further detail studies on the distribution of the molluscs along the coasts of this Peninsula are yet necessary before concluding remarks can be given.

Beach of Akaisi, Mutu

The beach stretching between Azigasawa at the north to Akaisi at the south, Mutu is a very long one, and consists in the main of small rounded to elongated pebbles consisting of shales from the Aziga-

sawa and Akaisi shale beds. These pebbles are uniformly distributed along the strand line, in back of which sand prevails. The beach is a very gently sloping one and intermingled in the uniformly distributed pebbles and sand, hardly no marine shells were found. In back of the sand of the beach is developed sand dunes of varied extension. Wave action does not appear to be strong, but probably the bottom control alone explains the absence of a molluscan fauna on this beach. Therefore, should the beach be raised and changed into a conglomerate, its marine origin could hardly be determined, owing to the absence of organic evidence.

Beaches with Fossils

Among the beaches observed by the writer, there are a few which have fossils strewn among the recent shells, and the fossils are so well preserved that they would easily be mistaken for recent shells unless the collector is familiar with them.

On the narrow beach of Anden on the northern shores of Oga Peninsula, Ugo is found a fairly large molluscan fauna in which such fossil shells as *Turritella saishuensis* YOKOYAMA, a characteristic Lower Pliocene shell and *Turritella andenica* OTUKA, a Pliocene fossil are intermingled. Besides these two species are also found a considerable number of other fossil molluscs. Their preservation is so good that to distinguish them from the recent shells upon either the state of preservation or natural coloration, is quite impossible.

On the beach of Kazusa-Minato facing Tokyo Bay, Kazusa are found some very well preserved specimens of *Arca granosa* LINNÉ, which are fossils washed out from the strata making the cliff bordering the beach. Although certain authors maintain that the specimens of *Arca granosa* represent recent shells, the writer is in the opinion that they are all fossil shells washed out from the neighboring cliff. His reasons for holding this view is that among the specimens of that species, many are in the form of concretions whose material consists of the rock of the neighboring cliff, in the cliff are found many specimens of *Arca granosa* of the same size, coloration and state of preservation as those found strewn on the beach. Further, there appears to be no record of living specimens of that species in the said region.

Found strewn on several beaches of Nanao Bay, Noto are found many specimens of fossil shells (molluscan as well as foraminferan) intermingled among the recent shells. These fossils have been washed

out from both the Pleistocene and Miocene strata which build the cliffs adjacent to the beaches, seeing that their occurrence in the strata is common. The preservation of their tests is remarkably good and to distinguish them from recent shells merely upon the state of preservation is difficult, if really possible. Besides the above mentioned kinds of fossils, also found in considerable numbers are shells of brachiopods. These brachiopods, so far as present knowledge is concerned, are those which are restricted to the Miocene in geological range, and to the borderland of the Japan Sea in their geographical distribution. Thus, the brachiopods also must be considered as fossils.

Fossils found strewn on beaches is not a rare fact, but collectors have neglected this fact and, erroneously have recorded them as recent shells on the one hand, or used them to extend the geographical distribution on the other. The writer, in future articles expects to describe other beaches, and to explain, if possible, the general statement given in the young lines of this article.

Classified List of Papers and Reports bearing on Oceanography Published in Japan during 1938-1939 (with Supplement)

(* articles in Japanese; § articles with abstract in foreign language)
Abbreviations for Titles and Periodicals.

Ann. Jap. .....Annotations Zoologicae Japonenses.

Bull. Biogeogr. Soc. Jap. .....Bulletin of the Biogeographical Society of Japan.

Bull. Earthq. .....Bulletin of the Earthquake Research Institute, Tokyo Imperial University.

Bull. Jap. Soc. Sci. Fish. .....Bulletin of the Japanese Society of Scientific Fisheries.

Ecol. Rev. .....Ecological Review, Institute of Biology, Tôhoku Imperial University.

Hyd. Bull. .....Hydrographical Bulletin (Suirô Yôho)

Jap. Jour. Astron. Geophys. .....Japanese Journal of Astronomy and Geophysics.

Jap. Jour. Genetics .....Japanese Journal of Genetics.

Jap. Jour. Limn. .....Japanese Journal of Limnology.

Jap. Jour. Zool. .....Japanese Journal of Zoology.

Jour .Fac. Sci., Hokkaidô Imp. Univ. Journal of the Faculty of Science, Hokkaidô Imperial University, Series 6, Zoology.

Jour. Ocean. .....Journal of Oceanography (Kaiyô Zihô).

Mem. Coll. Sci., Kyoto Imp. Univ. ..Memoirs of the College of Science, Kyoto Imperial University.

Mem. Mar. Obs. .....Memoirs of the Imperial Marine Observatory, Kobe.

Jour. Soc. N. A. Jap. .....Journal of the Society of Naval Architecture of Japan.

Jour. Geol. Soc. Jap. .....Journal of the Geological Society of Japan.

Jour. Geogr. .....Journal of Geography.

Jour. Met. Soc. Jap. .....Journal of the Meteorological Society of Japan.

Palao Trop. Biol. Sta. .....Palao Tropical Biological Station Studies.

Proc. Imp. Acad. .....Proceedings of the Imperial Academy.

Rec. Ocean. Wks. Jap. .....Records of Oceanographic Works in Japan.

Rep. Hokkaidô Fish. Exp. St. .....Report of the Hokkaidô Fisheries Experimental Station.

Rep. Marine Obs. .....Report (Ihô) of the Marine Observatory, Kobe.

Sci. Rep., Tôhoku Imp. Univ., Ser. 4..Science Reports of the Tôhoku Imperial University, Series 4, Biology.

Trans. Biogeogr. Soc. Jap. .....Transactions of the Biogeographical Society of Japan.

Trans. Sapporo Nat. Hist. Soc. ....Transactions of the Sapporo Natural History Society.

Umi to Sora .....Sea and Water.

Venus .....The Malacological Society of Japan, Kyoto Imperial University.

Zool. Mag. .....Zoological Magazine (formerly Dobutu-gaku Zasshi).

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